SEWAGE WORKS JOURNAL

Vol. I | APRIL, 1929 | No. 3

Special Articles

Syracuse Treatment Works

Activated Sludge Dried on Sand Beds at Tenafly, New Jersey

Chlorination of Settled Sewage

Fauna of Trickling Filters

Effect of Age of Solids on Digestion

Sewage Research

Operating Results at Pasadena

Sampling and Analyses at Worcester

Reviews of European Practice

OFFICIAL PUBLICATION OF THE FEDERATION OF SEWAGE WORKS ASSOCIATIONS

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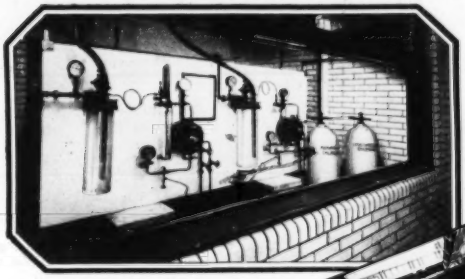

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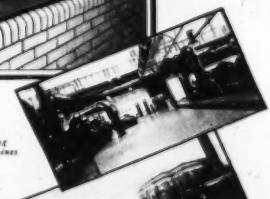

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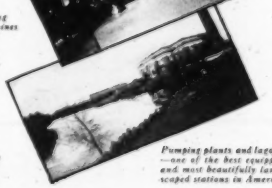

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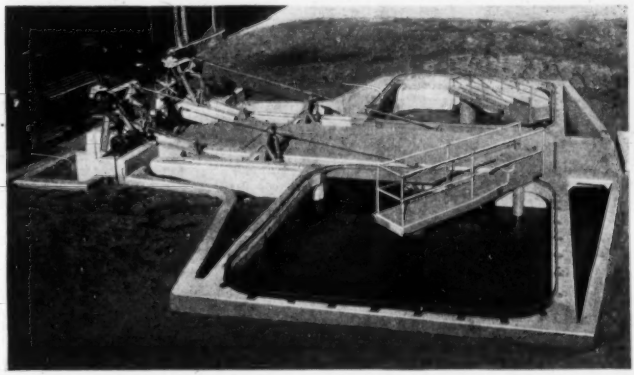

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Federation Affairs

Minutes of the Annual Meeting of the Federation Board of Control

Meeting of the Board of Control of the Federation of Sewage Works Associations was held at the offices of The Chemical Foundation, No. 85 Beaver Street, New York, on the 18th day of January, 1929, at 2:30 p.m.

The meeting was called to order by the Chairman, Mr. C. A. Emerson, Jr., who called the roll, which showed the following members of the Board were present:

Kenneth Allen, New York
John R. Downes, Bound Brook, N. J.
C. A. Emerson, Jr., Philadelphia, Pa. (Chairman)
J. J. Hinman, Iowa City, Iowa
H. E. Moses, Harrisburg, Pa. (Secretary-Treasurer)
Arthur E. Gorman, representing W. J. Orchard, Newark, N. J.

By proxy:

V. M. Ehlers, Austin, Texas
C. C. Kennedy, San Francisco, Calif.
W. T. Knowlton, Los Angeles, Calif.
Max Levine, Ames, Iowa
H. W. Streeter, Cincinnati, Ohio
L. F. Warrick, Madison, Wis.

Also present:

William W. Buffum, New York (Business Manager)

Reading of the minutes of the last meeting was dispensed with, as they were printed in the January issue of the SEWAGE WORKS JOURNAL which was available.

Mr. Moses read his report as Secretary-Treasurer, and upon motion of Mr. Emerson, which was seconded and adopted, this report was accepted. (See below.)

The Business Manager presented a report to Dec. 31, 1928, which was accepted with a vote of thanks to Mr. Buffum for his work.

It was reported that the application of the Missouri Sewage Works Association was received during November and referred to the Chairman of the Membership Committee, Mr. H. W. Streeter, who examined their constitution and reported that the constitution of the local association was in harmony with that of the Federation and recommended that their applica-

tion for affiliation be acted upon favorably by the Board. Motion was made by Mr. Allen that they be accepted, and this motion was seconded and carried.

It was reported that, through the instrumentality of Dr. Rudolfs and Mr. Downes, a subsidiary of the New Jersey Sewage Works Association had been formed under the name of the New Jersey Sewage Works Conference Group. This group has adopted a brief form of constitution. Members are to pay $1.10 as dues in the Conference Group. The object of the group is defined as an advancement of the art of sewage and trade waste disposal and encouragement of a friendly exchange of information and experience. It is further stated that the officers are authorized to affiliate the group with other groups or associations to form a Federation Board for the publication of a Journal and to act in accordance with the Constitution and By-Laws of the Federation of Sewage Works Associations.

Under authority of the Constitution, Dr. Rudolfs, the Chairman, made application for affiliation of the Conference Group with the Federation of Sewage Works Associations.

Motion was made by Mr. Emerson that the application of the New Jersey Sewage Works Conference Group be approved, and this motion was seconded, and carried.

An extended discussion was held on ways and means of increasing the membership of the Federation through acquisition of individual members and formation of sewage works associations in additional states.

Mr. Buffum requested that the Federation appoint a committee to advise with him concerning the advisability of cooperation with some of the requests made for assistance in research problems.

After some discussion on the subject, Mr. Hinman made a motion, which was seconded and adopted, that the Board authorize the Editor to arrange to procure abstracts at a total expenditure not to exceed $180.00.

There being no further business, the Board on motion adjourned.

Report of Secretary-Treasurer Made at the Annual Meeting Held in New York January 18, 1929

During the year 1928, as the outgrowth of the preliminary work carried on by a Committee of One Hundred, representing every section of the country, and later by four smaller committees working under a general chairman, the Federation of Sewage Works Associations was formed and the publication of the SEWAGE WORKS JOURNAL was begun. The first issue appeared October, 1928.

The first meeting of the Board of Control was held in Chicago during the Convention of the American Public Health Association on October 16, 1928.

The Chairman of the Board, C. A. Emerson, Jr., of Philadelphia, presided. The minutes of this meeting were printed in the January, 1929, issue of THIS JOURNAL.

The membership of the various organizations as reported to the Secretary at the end of 1928 is shown below. This total does not check with the total subscriber list of the Business Manager, since he had not received dues for some of the names listed. Consequently, his total is somewhat less and will gradually approach the total shown by the Secretary as the subscriptions for all of these names are sent to the Business Manager.

Name of Association	*Number of Members*	
Arizona Sewage Works Association	15	
California Sewage Works Association	120	
Central States Sewage Works Association:		
Illinois		
Wisconsin		
Indiana	62	
Iowa Wastes Disposal Association	57	
Maryland Water and Sewerage Association	44	
Pennsylvania Sewage Works Association	85	
Texas Sewage Works Association	28	
	—	411
Of groups now seeking entrance:		
Missouri Water and Sewerage Conference	77	
New Jersey Sewerage Conference	23	100
	—	—
Total		511

At the end of the year some preliminary work had been done in connection with other groups as follows:

New England Sewage Operators' Association
North Carolina Sewage Works Association
Oklahoma Water Works Conference
United States Public Health Service

The only money received by the Secretary-Treasurer has been dues from the various organizations, which has in turn been forwarded to the Business Manager.

These amounts, as shown below, do not in every instance correspond with the total membership since at times payment is made direct to the Business Manager and not through the Secretary-Treasurer.

Arizona Sewage Works Association	$ 15.00
California Sewage Works Association	105.00
Central States Sewage Works Association:	
Illinois	
Wisconsin	
Indiana	62.00
Maryland Water and Sewerage Association	35.00

Pennsylvania Sewage Works Association	85.00
Missouri Water and Sewerage Conference*	79.00
	$381.00

*Includes a duplication of 2 names.

H. E. MOSES,
Secretary-Treasurer.

New York State Sewage Works Association

A meeting was held March 26, 1929, in the office of Kenneth Allen, Municipal Building, New York City, for the purpose of organizing a New York State Sewage Works Association. There were fourteen present. A discussion was held concerning the need of an organization in New York State for the purpose of furthering the aims of the Federation of Sewage Works Association. It was agreed to meet in Albany in April for the purpose of completing the organization.

Mr. Kenneth Allen was made Temporary Chairman of the organizing group, Mr. W. T. Carpenter Temporary Secretary, and Mr. Earl Defendorf Chairman of the Membership Committee.

Further information concerning this group will be published in our next issue.

New England Sewage Works Association

Notice has been sent out concerning the program of the first meeting of the New England Sewage Works Association, which was formed for the purpose of interchanging information on sewage works subjects. The meeting will be held in conjunction with a meeting of the New England Health Institute, at the Hotel Bond, Hartford, Connecticut, Tuesday, April 23, 1929.

A registration fee of $1.00 will be charged for attendance at the program. On Tuesday evening, April 23, a banquet of the New England Health Institute, with a charge of $3.00, will be held for all those wishing to attend.

This meeting is in furtherance of the organization of a New England group under the leadership of Stuart E. Coburn of Metcalf and Eddy, Boston, Massachusetts. Notice of this meeting was given in the January issue of THIS JOURNAL, Vol. I, No. 2, p. 119.

The Hartford meeting will include the following interesting program on sewage research and sewage works operation:

Morning Session

N. E. Health Institute and N. E. Sewage Works Association. Chairman, Edward Wright, Assistant Engineer, Mass. State Dept. of Health.

9:30 "Some Newer Aspects of Sludge Digestion Problems," Prof. Gordon M. Fair, Harvard University.

10:30 "Design and Operation of Sewage Tanks," C. A. Emerson, Jr., Philadelphia, Pa.

11:30 "Difficulties with Sewage Plant Operation," J. R. Downes, Plainfield, N. J.

Afternoon Session

Chairman, Stephen DeM. Gage, Chief Engineer, R. I. State Board of Health.

1:45 "Formation of a New England Sewage Works Association." Discussion opened by Stuart E. Coburn, Boston, Mass.

3:00 "The Activated Sludge Method of Sewage Disposal," W. R. Copeland, Hartford, Conn.

3:30 "Value of Keeping Sewage Plant Records." Discussion opened by J. Frederick Jackson, New Haven, Conn.

4:00 "Round Table Discussion on Filter Plant Operation." Discussion opened by Roy S. Lanphear, Worcester, Mass.

Sewage Research

Encouragement and Coördination of Research

By Willem Rudolfs[1]

In spite of the fact that sewage disposal problems are rather universal it is often held that the study of such problems should be local in character, conducted by a group of municipalities, or, at best, possibly by some state agency. At present we are far from a country-wide encouragement of sewage research, although the Chemical Foundation, Incorporated, has for the last few years extended its helping hand for the stimulation of studies. The local Sewage Works Associations have done what they could, although a number of them were formed as a result of research elsewhere, or through the interest of engineers and operators who are interested in the results rather than for the stimulation of research. To date, we have no governmental department or any other agency which devotes itself to the general, fundamental problems. Much valuable work has been done by local authorities in states and cities, universities and colleges, industrial and other organizations, and it is encouraging that sewage research is growing, but serious attempts to encourage and coördinate the diverse activities have not been made. The U. S. Public Health Service has done most excellent fundamental work in stream pollution studies, has made available the results obtained and methods worked out, and in doing so has provided and is providing the basic material for local studies and interpretations.

Any one engaged in sewage research in this country must be constantly on the alert to find out what is being done elsewhere. He is helped by the more or less complete abstracts of papers found in the journals, notably in *Chemical Abstracts*, and the mimeographed abstracts supplied by the U. S. Public Health Service. There are no summaries published of the current literature, giving in addition to the results in the papers and reports critical comments or illuminating additions.

Those of us who are actively engaged in sewage research have no way of knowing what is being done at different places. This might lead to efforts which could have been expended in other directions or further along the same lines. We agree entirely that duplication of efforts is not to be feared, because two groups of investigators attacking the same problem might arrive at similar conclusions along different lines, but we hold that, with the comparatively small number of workers and the vast number of problems,

[1] *Chief, Dept. of Sewage Disposal, New Jersey Agricultural Experiment Station.*

much can be gained by coördination of research. It should be understood that by coördination is not necessarily meant a parceling out or dividing up of problems among the workers, but an effort to so correlate the studies that results of value may be produced in a shorter time. A preliminary attempt in the direction of such coördination was made last fall during the American Public Health Association meetings. Some twenty people interested and actively engaged in sewage research attended and enumerated the problems on which they were working or had been working on recently. This gave an inkling of the great variety of problems attacked, no two being the same.

It can easily be seen that several people attacking a number of problems should be closer together. Do similar conditions prevail in other countries? In Germany the Institute for Soil, Water and Air Hygiene is perhaps not sufficiently developed as yet to furnish the services we have in mind.

The First Annual Report of the Water Pollution Research Board of England has just been received and a few quotations will indicate the purpose and functions of this Board. The Water Pollution Research Board was created in 1927 and a director of research appointed at the same time by the Committee of the Privy Council for Scientific and Industrial Research. The function of the Board was threefold: (1) "To collect and collate all pertinent scientific and technical information, so that it may be readily available for practical application by those who are concerned with water supply and the disposal of polluting liquids; (2) to encourage and coördinate relevant scientific research in this country (England); and (3) to undertake such investigations as are necessary in the public interest and not otherwise provided for."

The Board has already been providing monthly summaries of current literature. These summaries will form only a part of the information they hope to make available. They contemplate the issue of reports in which valuable information on a particular problem will be brought together and reviewed, so as to form a considered and authoritative statement. The report states that "The investigations carried out hitherto in this country (England) have been somewhat scattered and isolated, and very little has been done in the way of coördinated attacks upon the problems." It seems that this statement would hold as well for this country (U. S. A.). The Board considers that four problems of waste disposal are in special need of further investigation at the present time, *viz.*, factory waste disposal, the activated sludge process, the dewatering of sludge and the production of gas from sewage sludge. They state that few effective means for trade waste disposal are available. With our present knowledge, the best sewage purification process, the activated sludge process, should receive intense study because there is available "little exact knowledge of the process; it is, for example, a matter of debate whether it is mainly biological

or physico-chemical." The dewatering of sludge from digestion units is a pressing problem as has been pointed out by Dr. Mohlman in an earlier issue of THIS JOURNAL.

We have here, then, a good example of encouragement and coördination of sewage research. For several years, when occasion arose, we have emphasized the need of encouragement and coördination of research. With the Federation of Sewage Works Associations a going concern, could not the Federation study this question and report and devise means whereby the desired result could be accomplished?

Reduction of the Biochemical Oxygen Demand of Sewage by Chlorination[1]

BY H. G. BAITY[2] AND F. M. BELL[3]

Purpose in Chlorination Study

For more than twenty years chlorine has been used as a sterilizing agent for bacterial destruction in water purification and sewage treatment works. Its germicidal properties have been well investigated experimentally and proved by practice, so that it has now become almost universally used where high degrees of bacteria removal are desired. But not until the last year or two has chlorine been considered as an agent capable of reaction with the organic materials of sewage in such a way as to reduce the biochemical oxygen demand. Several investigators have found an indication of such an effect in laboratory-scale experiments, and it is understood that others have recently observed the same phenomenon in plant-scale experiments under operating conditions. With ideal conditions for such a study existing at the Chapel Hill sewage treatment plant, an investigation was begun in the spring of 1928, and continued for two months on a plant-size scale, to determine the effects on the biochemical oxygen demand of settled sewage of various dosages of chlorine. This study is one part of an extensive program of investigation on the uses of chlorine in sewage treatment which is in progress.

Methods and Technique

Chapel Hill is a university town of about 5500 inhabitants. The sewage is strictly domestic in character and relatively weak, but carries a considerable amount of grease from the dining halls and restaurants. The average daily flow is about 450,000 gallons. The sewage reaches the treatment works, about 1 1/4 miles from town, in a fresh state. The treatment plant consists of bar screens, a circular Imhoff tank and sludge beds. The tank is heavily overloaded, the retention time of the sewage in the flowing-through chamber being only 45 minutes, and the removal of settleable solids is only 75 to 85 per cent. The settled sewage is discharged directly into a small stream with highly variable flow.

Chlorination Apparatus.—For the purposes of this and other experiments, a solution-type Wallace and Tiernan chlorinator, with a capacity of 50 pounds per day, was installed at the plant, and so arranged that the

[1] *Paper presented before the North Carolina Sewage Works Association, November 21, 1928.*

[2] *Associate Professor of Sanitary and Municipal Engineering, University of North Carolina.*

[3] *Research Assistant in Sanitary Engineering, University of North Carolina.*

chlorine solution could be applied either to the influent or effluent of the Imhoff tank. For this study the chlorine was introduced into the effluent sewage in a manhole immediately below the plant, where ideal mixing was obtained. Samples of the unchlorinated sewage were collected from the effluent channel of the tank. Samples of the chlorinated sewage were taken from another manhole about 300 feet farther down the line between the tank and the creek. The rates of chlorine application during the experiment were varied from 5 to 15 parts per million, on the basis of the sewage flow.

Time of Experiment.—The period covered by this study was April 17 to June 2, 1928. During this time the conditions governing the quantity and quality of the sewage were practically stable. The temperature of the effluent sewage varied between 13° and 20° C., and the pH between 6.6 and 6.9.

Sampling.—By simultaneous sampling of the chlorinated and unchlorinated sewage, the samples were identical in all respects except for the applied chlorine. To further insure this condition, the daily samples were taken over a period of one to two hours at 10-minute intervals, at the same time each morning when the flow was fairly constant, and composited. The free chlorine content of each sub-sample of chlorinated sewage was determined after 10 minutes' contact and the results averaged. The temperature, pH, rate of chlorine feed and rate of sewage flow were taken several times during the sampling period and the results averaged to obtain the mean.

Laboratory Technique.—Immediately after sampling, the samples were taken to the laboratory, and dilutions made for biochemical oxygen demand. The dilution method was used for this test. The water used for dilution was distilled water, fully oxygenated and containing 500 p. p. m. of sodium bicarbonate, which had been stored in the laboratory for several weeks at constant temperature. The incubation bottles were chemically clean, and were sealed in a water bath during incubation. The proper concentration was determined by experiment. Dilutions were prepared in clean glass jars, those of the chlorinated sewage being tested each time for residual chlorine. In most cases the free chlorine disappeared after dilution, otherwise the jars were allowed to stand until no more chlorine was present. The dilutions of chlorinated sewage were then reseeded with 1 cc. per liter of unchlorinated sewage that had been strained through cotton, and in the computations correction was made for this seeding material. Duplicate sub-samples were run for chlorinated and unchlorinated samples, and a dilution-water blank was also incubated. The temperature of incubation was 20° C., and the time was 5 days. Once a week additional samples were run for the 1- and 15-day demands. The Winkler method was used for all dissolved oxygen determinations.

Results for each series were averaged, corrections applied, and the B. O. D. values calculated.

Results.—It was found that a chlorine dosage of less than about 7.5 p. p. m. produced no residual after 10 minutes' contact; about 9 p. p. m. was required to give a residual of 0 to 0.1 p. p. m.; from 10 to 12 p. p. m. for a free chlorine excess of 0.2 p. p. m.; and 12 to 15 p. p. m. to produce a residual of 0.5 p. p. m. The temperature of the sewage within the limits of the experiment did not appear to affect these relationships, nor did it seem to have any effect on the reduction of biochemical oxygen demand. The pH values of chlorinated and unchlorinated samples were in all cases the same.

The biochemical oxygen demand of the unchlorinated settled sewage ranged between 36 and 148 p. p. m. during the period of the experiment, with a mean of 86. The results showing the effect of chlorination on reduction of biochemical oxygen demand are summarized in the following table, indicating the B. O. D. decrease accompanying different amounts of residual chlorine. These computations have been made by averaging the results in each residual-chlorine group.

Chlorine Dosage P. P. M.	Residual Chlorine 10 Min. P. P. M.	B. O. D. Unchlorinated Samples P. P. M.	B. O. D. Chlorinated Samples P. P. M.	Per Cent Reduction
5–7.5	0	77.0	71.1	7.4
8–9	Trace	94.3	79.6	15.5
10–15	0.2–0.5	85.2	48.9	42.7
All samples (39)		85.8	58.6	31.7

When chlorine was applied in quantities insufficient to give a residual after 10 minutes' contact there seemed to be little effect on the B. O. D. In samples dosed with 5 or 6 p. p. m., or about one-half the dose required to give 0.2 p. p. m. residual, there was practically no decrease. With a dosage of about 9 p. p. m., about three-quarters that required for a residual of 0.2 p. p. m., there was observed an appreciable oxidation effect. The maximum effect of 42.7 per cent reduction in B. O. D. was found with a dosage of 10 to 15 p. p. m. and an excess-chlorine value of 0.2 p. p. m., or greater. However, it was observed that in samples heavily chlorinated and with residual chlorine in excess of 0.2 p. p. m. the results obtained were little, if any, better than those found with a 0.2 p. p. m. excess.

It seems uneconomical and wasteful to apply chlorine in greater concentration than that necessary to give a residual of several tenths of a part per million. Owing to the wide hourly fluctuations in sewage flow, the matter of adjustment of dosage presents a problem. If the feed of the chlorinator is set for the peak flow, there is wastage of chlorine; if it

is adjusted to the mean flow, the peak flows go under-treated and with the B. O. D. practically unchanged. It is the peak flows that demand treatment most. With plants other than very small ones, it would be advisable to install automatic chlorinating equipment, or else proportion the chlorine dosage to the sewage flow manually.

The one-day biochemical oxygen demands on samples which had been fully chlorinated were found to be very low in comparison with the 5-day demands—much lower than the theoretical formula would give, although the samples were seeded. This indicates a delay in bacterial activity, due to the chlorination. In samples incubated for 15 days there was observed about the same relative decrease in B. O. D. in the chlorinated portions as was found for 5 days, indicating that there is a real oxidizing effect, a true reduction of the biochemical oxygen demand.

Practical Application of Results

The applications of these results to actual practice are almost too obvious to require elaboration. A process capable of decreasing the oxygen requirements of liquid wastes by 30 to 40 per cent may have many uses that are important and economic. Actually, it is the same thing as providing means of increasing stream-flow by the same amount. It is certainly not a cure-all, nor a process which will supplant other established types of treatment. But when used judiciously, it seems entirely possible that chlorination may be of even greater service to the sewage treatment world than it has been in the past.

If there were no effect on the organic constituents of sewage, chlorine treatment would doubtless be justified in many cases for the retarding action it exercises on bacterial decomposition. By its use the intense biological activity requiring a large oxygen supply could be delayed until the pollutional material has been carried downstream to a point where, by increased dilution, the oxygen requirements can be met. But with actual reduction in the biochemical oxygen demand, and with high efficiency as a bactericidal agent, chlorine has three strong arguments to recommend it. Some examples of the use of chlorine as an oxidizing agent are the following:

(1) For retarding decomposition in a small stream until settled sewage can be carried to a point downstream where adequate dilution is afforded.

(2) As a permanent adjunct to treatment plants which, although functioning efficiently, are not affording the required degree of treatment.

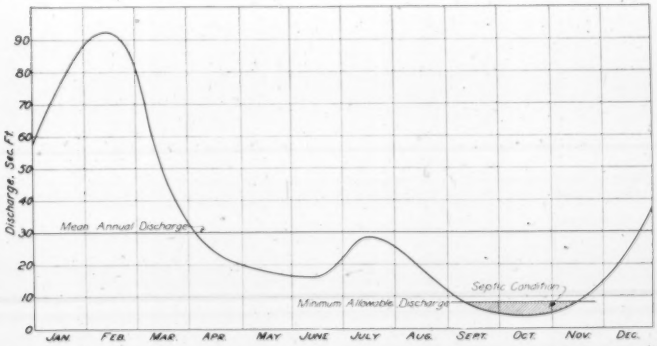
(3) As an adjunct to treatment works that are overloaded and functioning inefficiently.

(4) For intermittent use on raw, settled or filtered sewage during the dry seasons of the year when stream-flow is at a minimum.

This latter use of chlorination appears to be the one of greatest utili-

tarian and economic significance. Sewage treatment plants must be designed for conditions of *minimum* flow in streams which have wide seasonal variations in discharge. It is believed that much money could be saved by building treatment works with capacities and efficiencies based on 150 per cent of the minimum stream-flow, and depending upon chlorination to handle 35 per cent of the load during the critical periods. This can be illustrated more clearly by means of an example.

In the accompanying figure is shown a smoothed hydrograph for a typical small stream in North Carolina, which illustrates the wide monthly and seasonal variations in flow that are characteristic of such streams in this section of the country. The minimum mean monthly flows frequently amount to only 10 to 12 per cent of the mean annual flows, while the



Smoothed Hydrograph for Sugar Creek, Charlotte, N. C., for 1926, Showing Estimated Effect of 1 M. G. D. Settled Sewage.

minimum mean daily flows are often below 5 per cent of the mean annual discharge. Moreover, these depressions in flow occur during the late summer and early fall months, when temperatures are high and rates of biochemical oxygen demand greatest.

Let it be assumed that the stream shown in the figure receives one million gallons per day of settled sewage having a 2-day B. O. D. of 50 p. p. m. To avoid nuisance conditions, the required stream-flow would have to be about 8 cu. ft. per sec. The hydrograph shows that such a discharge is maintained during most of the year, but from early September until late November the flow is below the allowable minimum. To provide for this critical condition two alternatives exist: some form of secondary treatment, such as trickling filters, must be added to the plant; or

chlorination may be employed temporarily to tide over the three months' period.

Cost of Chlorination

The advantage in the use of chlorine under such conditions is apparent when costs are considered. In the case given above the cost of addition of trickling filters to the 1 m. g. d. treatment plant would be about $60,000. The fixed charges, covering interest, sinking fund and depreciation would amount to about $8000 per year. Units of this type must of necessity be in service all of the time to maintain their efficiency, and the annual operating cost would be about $1800. This amounts to a total cost per year of $9800. If chlorination were employed, the apparatus could be installed for $1500, or less, and would be operated only when stream-flow conditions demanded it. The fixed charges for such an installation would be about $300 a year, and the cost of operation for 3 months each year, including repairs and chlorine, is estimated at $700, a total yearly expense of $1000, or about one-tenth the cost of trickling filters.

This example is given only to illustrate the possibility of economic use of chlorine in such special cases. It should be clear that other types of treatment are not supplanted. Chlorination is limited in efficiency, and cannot be employed alone where a high degree of removal of organic solids is required. But it may be used to supplement other processes. Each type of treatment has its proper place and use; chlorination is merely a newly recognized form of oxidizing treatment that will find its place.

Conclusions

From this study the following conclusions may be drawn:

(1) That chlorine treatment of sewage does exercise a very marked effect in reducing the biochemical oxygen demand.

(2) That its application in amounts insufficient to produce a residual causes a positive, but small, degree of oxidation. It was found that dosages of 5 to 7.5 p. p. m., with zero residual, diminished the B. O. D. by 7.4 per cent.

(3) That increased dosage, within limits, results in increased oxidation. Sewage dosed with 8 to 9 p. p. m. of chlorine, with residuals from 0 to 0.1 p. p. m., indicated a B. O. D. reduction of 15.5 per cent.

(4) That the economic dose is that amount which produces a residual of about 0.2 p. p. m. Samples which had received 10 to 15 p. p. m., with excess chlorine of 0.2 to 0.5 p. p. m., showed a decrease in B. O. D. of 42.7 per cent.

(5) That it is not economical to apply chlorine in excess of that necessary to give a 0.2 p. p. m. residual, as very little increased oxidation occurs with greater rates of dosage.

(6) That the B. O. D. reductions are permanent, as 15-day incubations showed relatively the same effect as 5-day samples.

(7) That in fully chlorinated sewage there is a retarding action on biological activity, as indicated by 1-day incubations. Chlorination would thus permit sewage to be carried downstream to adequate dilution before rapid decomposition sets in.

(8) That chlorination of sewage for B. O. D. reduction can be advantageously and economically applied in many cases, particularly where plants are overloaded, or slightly inadequate to protect stream quality, or to tide over dry periods of the year.

Acknowledgments

The authors wish to express their thanks to the town of Chapel Hill and Mr. E. M. Knox, former City Manager, for their interest and cooperation in providing at considerable expense the facilities for this study, to the Chlorine Institute for furnishing the chlorination equipment and chlorine, and to Mr. L. H. Enslow, Sanitary Engineer of the Chlorine Institute, for his many valuable suggestions.

The Fauna of an Experimental Trickling Filter

BY WILLIAM W. FRYE AND ELERY R. BECKER[1]

Introduction

In order that we may successfully study the processes involved in the transformation of raw sewage, it is necessary to know what animal life is present. It is a definitely established fact that bacteria are essential for decomposition of the sewage constituents, and the study of these organisms has been the major problem of the biological workers in this field. Associated with the bacteria and other flora found in sewage and industrial wastes there is a wealth of animal life which has been given very little attention. The films and liquid contents of Imhoff tanks and trickling filters present one of the most densely populated environments known. The fauna present has never been adequately studied to the extent of giving to this group a definite rôle in the active processes of decomposition. In this report a survey of the fauna is given, and further work is now being organized to continue the studies.

The materials studied were collected from an experimental lath filter, operating under controlled conditions. The temperature of the filter room and supply tank varied but a few degrees during the entire investigation. A solution of skim milk made up the waste which was added to the filter. At certain periods during the investigation changes were made in the rate of flow and concentration of the waste. This skim milk solution is markedly different from ordinary sewage in that a considerable amount of the organic content is the carbohydrate lactose.

Preliminary investigations were started in September, 1926. At that time a tile and also a cinder filter were in operation. Observations were made concerning suitable methods of collecting material and laying a foundation for subsequent work. These filters were discontinued early in January, 1927.

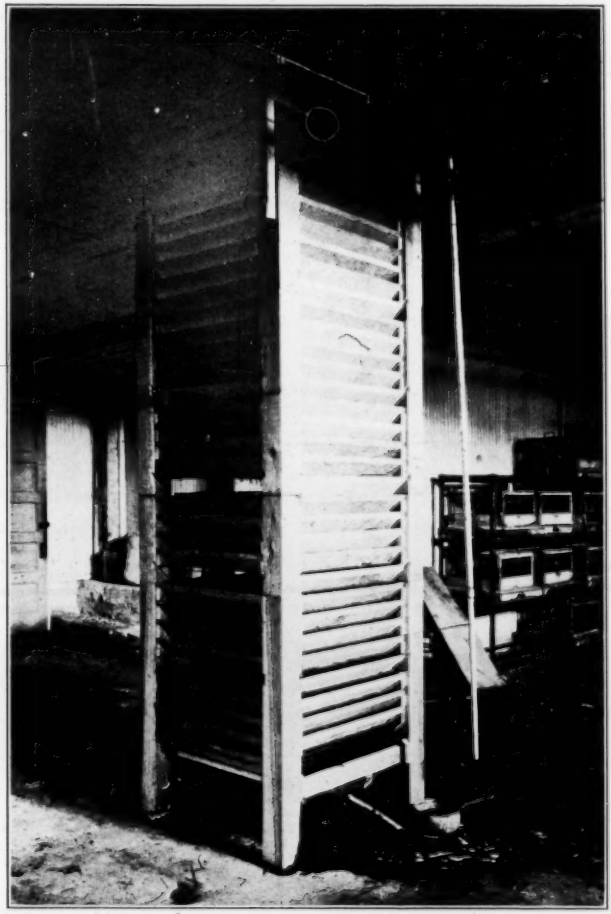
The lath filter, which is the basis of this report, was put into operation February 14, 1927, with the object of determining and studying the animal life present at each depth.

Literature

The process of sewage decomposition is for the most part biological. Investigators have shown that the bacteria present are largely responsible for the digestion of organic matter. The study of the fauna, which exists with the bacteria, has not been given careful consideration, until recent years.

In 1918 Wenrich made observations of animal forms inhabiting the films of sewage filters taken from the Plainfield, New Jersey, treatment

[1] *Dept. of Zoology, Iowa State College, Ames, Iowa.*



View of the Experimental Trickling Filter.

(The authors wish to thank the Iowa Engineering Experiment station for the use of this photograph.)

plant. In 1921 and 1922 the New Jersey Agricultural Experiment Station under the direction of Dr. R. O. Smith, specialist in charge of the substation, started an investigation of the fauna in Imhoff tanks and trick-

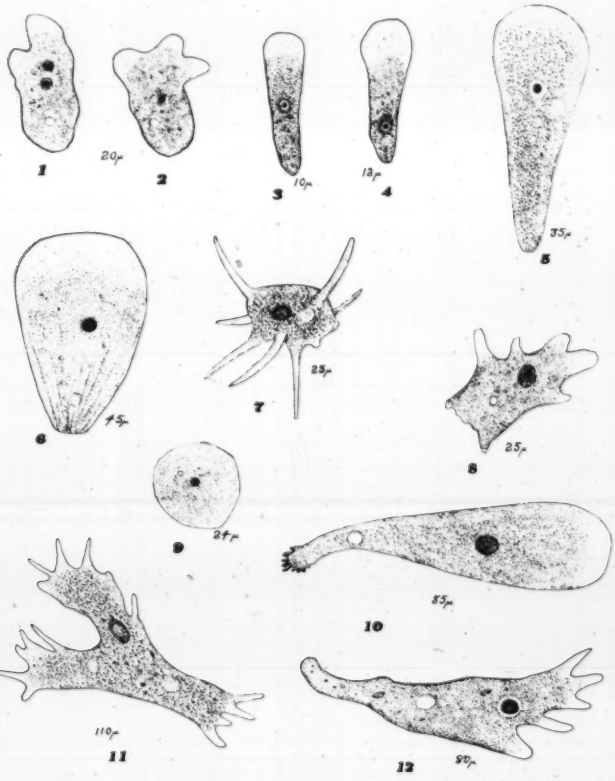


PLATE I

Fig. 1, *Dimastigamoeba gruberi*, with two nuclei. Fig. 2, *Dimastigamoeba gruberi*. Fig. 3, *Vahlkampfia limax*. Fig. 4, *Vahlkampfia limax*, showing movement. Fig. 5, *Vahlkampfia albida*. Fig. 6, *Amoeba verrucosa*. Fig. 7, *Amoeba radiosa*. Fig. 8, *Amoeba sp.* Fig. 9, *Amoeba sp.* Fig. 10, *Amoeba villosa*. Fig. 11, *Amoeba proteus*. Fig. 12, *Amoeba sp.*

ling filters. In 1923, Hausman, Crozier and Harris published the results of some preliminary work. A census of the fauna was taken every month

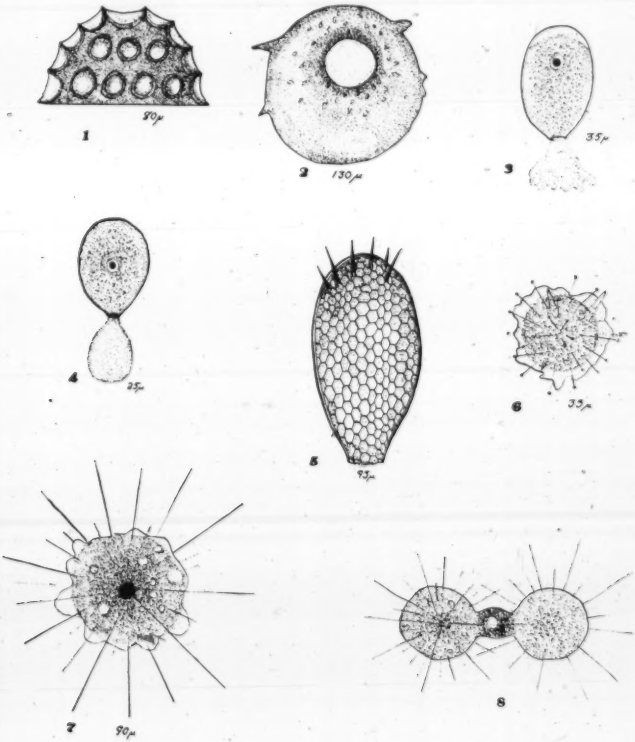


PLATE II

Fig. 1, *Arcella vulgaris*. Fig. 2, *Centropyxis aculeata*. Fig. 3, *Chlamydophrys sp.* Fig. 4, *Chlamydophrys sp.* Fig. 5, *Euglypha alveolata*. Fig. 6, *Vampyrella lateritia*. Fig. 7, *Actinophrys sol.* Fig. 8, *Actinophrys sol.* showing division.

from various levels of the filters. A check was made as to the effect of temperature, season, sloughing periods and the quality of the final effluent on the filter fauna. Their data show that the numbers and location of

the ciliates fluctuate in an irregular manner. The rhizopods appeared to be fairly constant in the upper portions of the filter, while the nematodes

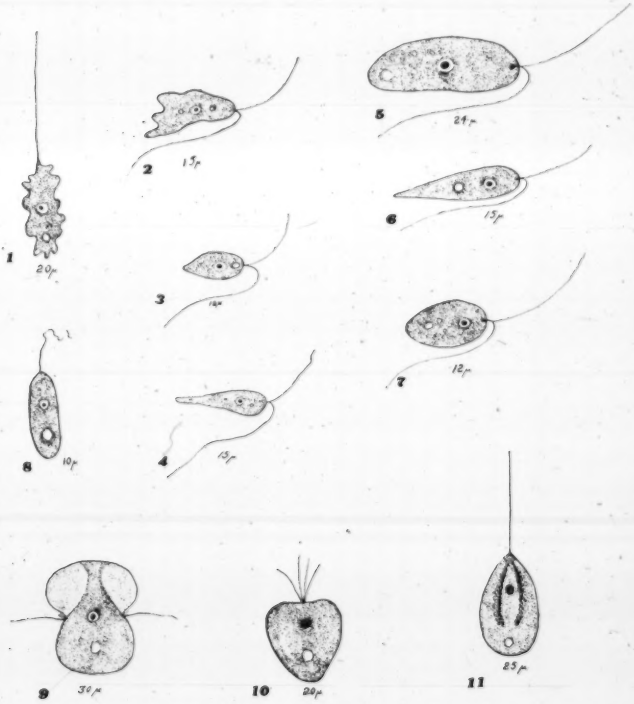


PLATE III

Fig. 1, *Mastigamoeba sp.* Fig. 2, *Cercobodo sp.* Fig. 3, *Cercobodo ovatus.* Fig. 4, *Cercobodo longicauda.* Fig. 5, *Bodo caudatus.* Fig. 6, *Bodo mutabilis.* Fig. 7, *Bodo lens.* Fig. 8, *Monas sp.* Fig. 9, *Trepomonas agilis.* Fig. 10, *Tetramitus sp.* Fig. 11, *Petalomonas trichophorum.*

were found to be more abundant toward the bottom. From October to April the nematodes and annelid worms were found to be more numerous, especially in the lower portion of the filter. Brief reference was made to

the part which might be assigned to these worms in connection with the annual spring sloughing of the films.

In the investigation of Imhoff tanks, Hausman (1923) found that the

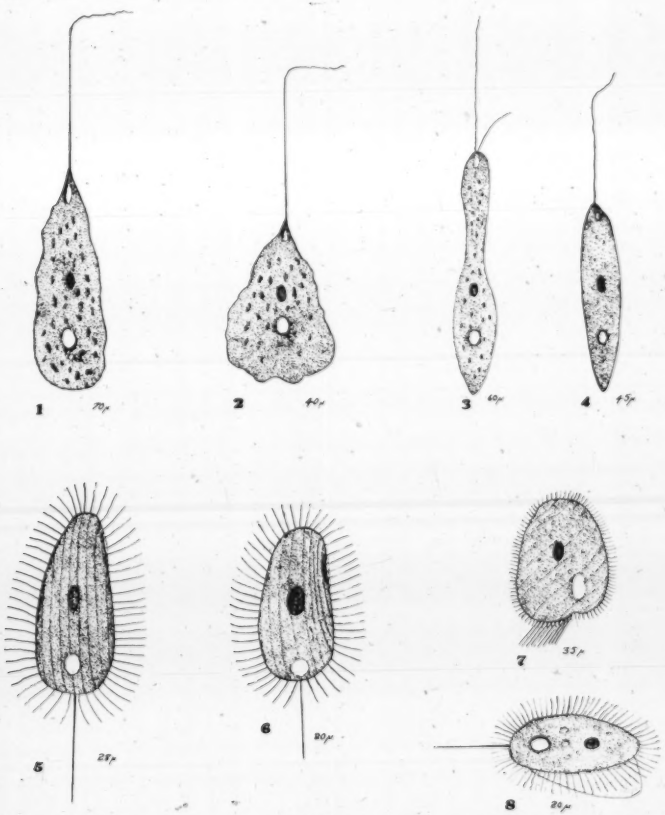


PLATE IV

Fig. 1, *Peranema trichophora*. Fig. 2, *Peranema trichophora*, contracted. Fig. 3, *Distigma proteus*. Fig. 4, *Euglena sp.* Fig. 5, *Uronema marina*. Fig. 6, *Uronema sp.* Fig. 7, *Cinetochilum margaritaceum*. Fig. 8, *Cyclidium glaucoma*.

small flagellates were more common than the ciliates. In a later report Hausman (1923) gave the results of a continuation of the month-by-month enumeration, as begun by Crozier and Harris in 1921 and 1922.

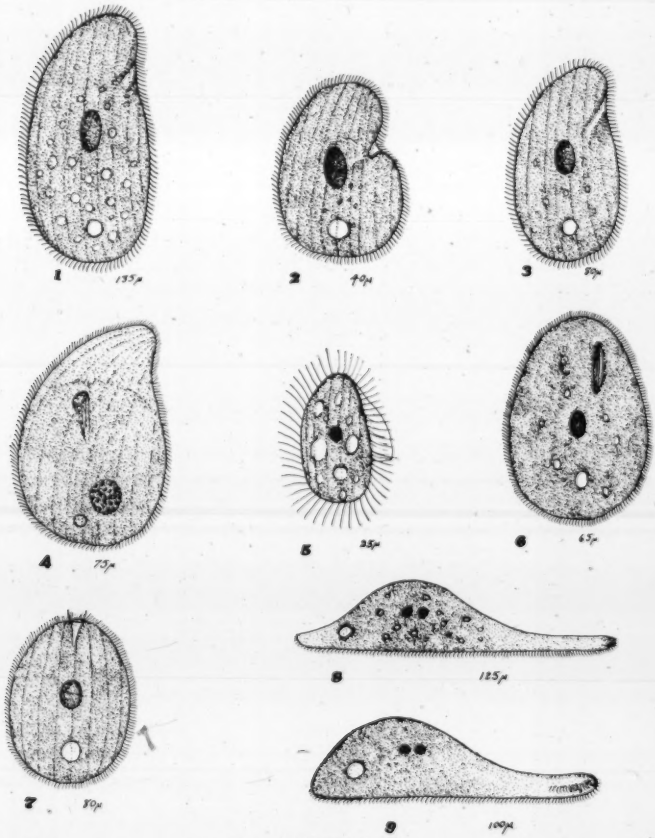


PLATE V

Fig. 1, *Colpoda helia*. Fig. 2, *Colpoda inflata*. Fig. 3, *Colpoda sp*. Fig. 4, *Chilodon cucullus*. Fig. 5, *Pleuronema chrysalis*. Fig. 6, *Glaucoma scintillans*. Fig. 7, *Prorodon teres*. Fig. 8, *Lionotus fasciolo*. Fig. 9, *Lionotus sp*.

The counts and cycles of the two investigations, covering a period of two years, give a fairly accurate account of the fluctuations of the fauna

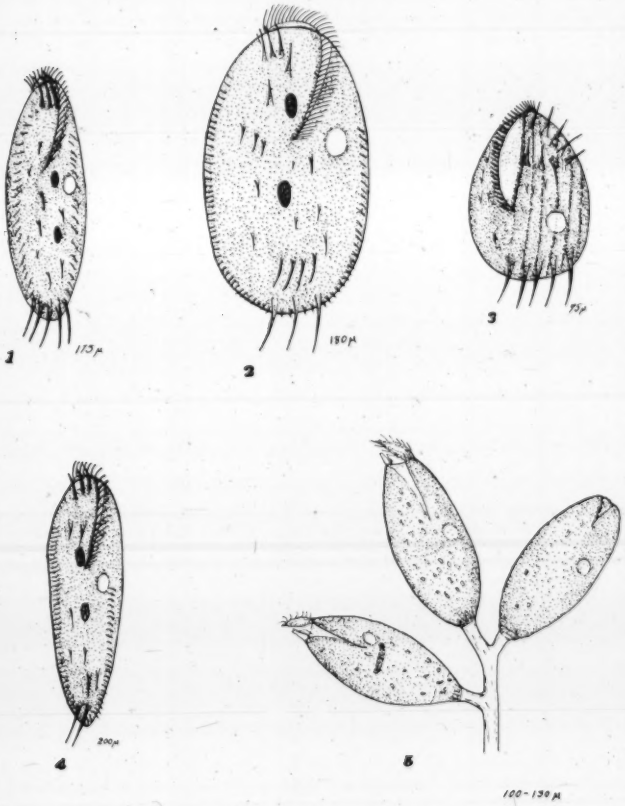


PLATE VI

Fig. 1, *Oxytricha pellionella*. Fig. 2, *Stylonychia pustulata*. Fig. 3, *Euplotes charon*. Fig. 4, *Pleurotricha lanceolata*. Fig. 5, *Opercularia berberina*.

throughout the year. Hausman also mentions the possible rôle of protozoa and worms in the sloughing process of filters. It was noted that

at the time of sloughing *Vorticella* and *Opercularia* increased in number of individuals per cubic centimeter of material. Before sloughing began, the annelids and nematodes reached a maximum in number of individuals per cubic centimeter of the material collected. The conclusions were that the stalked forms which covered the rocks, after the sloughing and before a new film was formed, aided in the formation of a new film. These stalked forms were also considered important with respect to their excretions into the filter bed. The annelids and the nematodes helped to loosen the film by their continual migration, making the film very porous and thus helping to accelerate the sloughing.

Lackey (1925) studied the ecology of Imhoff tanks, and later stated that it is possible that the protozoa afford a criterion as to the proper working conditions of the tanks. He noted that with foaming and poor digestion there was a decided increase in protozoa. When the solids in the tanks were at a minimum the protozoa decreased. It was stated that the fauna may add some nitrogen to the sludge, either from their bodies or by nitrification. Lackey (1925) also states that when a tank functioned normally, there were but few protozoa present, 20,000 flagellates and 2000 ciliates per cubic centimeter of fluid. When a tank foamed the number of flagellates increased to 250,000 and the ciliates to 20,000 per cubic centimeter. Every tank which foamed showed a similar increase.

In 1926 Lackey found that certain forms, which were normally rare in the Imhoff tank, may at times occur in such large numbers as to be the predominating forms. The investigation also showed that the percentage of solids largely determined the aggregation of flagellates in the tanks. Two years of careful study of one particular tank failed to indicate a seasonal factor even for certain genera of the ciliates, as was thought to be the case in 1924. The statement was made that there seemed to be a direct relation between the chemical end-products and animal life present, this being explained somewhat by the fact that when high concentrations of carbon dioxide were present large numbers of protozoa occurred. Lackey (1926), in his study of trickling filters, indicated that sloughing was a seasonal event due to the nature and changes of the flora and fauna present in the films. It was also noticed that when the protozoa attained their greatest number the fungi were fewest and vice versa. As to the variations within the animal groups, it was found that when one group decreased another group increased.

Rudolfs and Heukelekian (1926) gave the results of some attempts at partial sterilization of the Imhoff tanks. The object was to find one or two chemicals which could be used to reduce the number of protozoa, without affecting the bacterial count, so that the protozoa might be eliminated from the tanks if it should ever become necessary. It was

found that by using copper sulphate and mercuric chloride, in concentrations varying from one part in 100,000 to one in 1,000,000, the protozoa were markedly decreased, and bacterial growth was stimulated. Other chemicals were used with variable results.

Methods

1. Construction of Lath Filter.—The filter consisted of six sections of ordinary wood building laths, two feet square and one foot deep, with four inches of space between the sections for convenience in sampling and additional aeration. The laths were placed about one and one-fourth inches apart with alternate layers at right angles. About four inches above the uppermost section was placed a perforated tray, two feet square, which served as a distributing device. The perforations were of different sizes ($^3/_{16}$ to $^1/_2$ inch in diameter), and decreased in size as the distance from the tipping trough increased, thus helping to give an even distribution of waste. A double grooved tipping trough supported across the middle of the tray served as an automatic dosing device.

The upper four sections of the filter were of new lath. The two lower sections had been used in previous experiments at the same depths. The latter were placed on the bottom, thus serving to prevent contamination of the new with cysts which were undoubtedly present in the used sections.

2. Operation of the Filter.—The waste treated was prepared in a supply tank on the second floor of the building and piped to the filter in the basement. The waste was applied to the filter for 10 to 14 hours daily with a rest period of 14 or 10 hours, respectively.

3. Sampling and Examination of Material.—The sampling methods used for chemical and bacteriological analyses were not satisfactory for use in studying the fauna of the filter. The organisms are found in the films adhering to the laths and relatively few are found in the liquid passing from one section to the next. Examination of the effluents from different depths showed but a few forms and did not give a true distribution. Both the liquid and films were collected to get a true distribution at each depth.

Samples were taken in the morning, shortly after the filter was started, and again late in the afternoon. In collecting material from the various parts of each section a long glass pipette and rubber bulb proved to be very satisfactory. This device made it possible to scrape loose the films from the interior of the sections. Along the sides one could reach between the lath strips, thus collecting a portion of material from all parts of each depth. The samples were placed in sterile glass vials and were examined immediately in the laboratory. If samples were left standing for any length of time many of the forms died. This was especially true of the nematodes and rotifers.

Drawings which appear in this paper were made from living specimens in most cases. The measurement of individual forms, as they appeared in the samples, are found directly below each drawing. An attempt was made to fix and stain specimens by the regular staining methods suggested by Calkins (1913). These methods were not satisfactory for larger forms but small flagellates were nicely stained without any noticeable distortion of the animal. It would not have been possible to classify these smaller forms without the use of stained material. For making drawings and for classifying it was necessary to kill the organism to enable one to locate certain structures. Vapors of osmic acid were satisfactory for bringing out the cilia and flagella. Iodine solution was better for bringing out internal structures such as the nucleus and granules. Both methods may be used without much distortion of the organism.

Samples from each depth were examined and the forms were listed according to their abundance under varied conditions of flow and concentration of waste.

Experimental Data

1. Hydrogen-Ion Concentration of Samples.—The hydrogen-ion concentration of the effluents of various depths ranged from pH 6.7 to 8.0. The effluent from the first foot remained approximately neutral. The alkalinity increased in samples from the lower levels. After the waste material was changed from 1 per cent solution of milk, flowing at the rate of 800,000 gallons per acre per day, to 2 per cent, the pH of the effluent from the first foot fell to 6.7, slightly below the neutral point. At the same time there was a decided decrease in numbers of protozoa in the upper levels. The metazoan forms increased in the first section soon after the change was made.

The hydrogen-ion concentrations of the effluents from each foot of the filter are shown in Table I. The pH values are arranged according to the rate of flow or concentration of waste.

TABLE I

HYDROGEN-ION CONCENTRATION OF SAMPLES

Date	% Concentration of Milk	Rate of Flow Gallons per Acre per Day	Depth of Filter in Feet					
			1	2	3	4	5	6
2/16	1/2	800,000	7.2	7.6	7.8	7.8	7.8	7.8
2/22	1/2	800,000	7.1	7.4	7.8	7.9	7.9	7.9
2/27	1/2	800,000	7.1	7.4	7.8	7.8	7.9	7.9
3/1	1/2	800,000	7.2	7.5	7.7	7.8	7.8	7.9
3/29	1/2	1,600,000	6.9	7.6	7.9	7.9	7.9	7.9
4/22	1/2	1,600,000	7.0	7.6	7.8	7.8	7.9	7.9
5/24	1/2	1,600,000	7.0	7.8	7.8	8.0	8.0	8.0
6/15	1	800,000	6.9	7.7	7.7	7.8	7.9	7.9
6/27	1	800,000	6.9	7.8	7.8	7.9	8.0	8.0
7/20	2	800,000	6.7	7.5	7.9	7.9	8.0	8.0

2. Protozoa and Metazoa Encountered in Trickling Filter.—Table II gives a list of the protozoa and the metazoa which were found in the six depths and dosing tank of the experimental trickling filter.

TABLE II

TRICKLING FILTER PROTOZOA AND METAZOA

1. Protozoa

Sarcodina

Common	*Rare*
Dimastigamoeba gruberi	Amoeba proteus
Vahlkampfia limax	Amoeba verrucosa
Vahlkampfia albida	Amoeba villosa
Amoeba radiosa	Amoeba sp.*
Amoeba sp.*	Vampyrella lateritia
Euglypha alveolata	
Chlamydophrys sp.*	
Actinophrys sol.	
Centropyxis aculeata	
Arcella vulgaris	

Mastigophora

Monas sp.*	Mastigamoeba sp.*
Cercobodo ovatus	Oicomonas socialis
Cercobodo longicauda	Bodo mutabilis
Cercobodo sp.*	Euglena sp.*
Bodo caudatus	Anthophysa vegetans
Bodo lens	Tetramitus sp.*
Distigma proteus	
Peranema trichophora	
Trepmonas agilis	

Infusoria

Chilodon cucullus	Colpidium striatum
Colpoda inflata	Glaucoma scintillans
Colpoda sp.*	Prorodon teres
Cinetochilum margaritaceum	Stylonychia pustulata
Lionotus fasciola	Podophyra sp.*
Lionotus sp.*	Paramecium caudatum
Euplotes charon	Opercularia berberina
Cyclidium glaucoma	
Pleurotricha lanceolata	
Oxytricha pellionella	
Uronema marina	
Uronema sp.*	
Vorticella sp.*	
Pleuronema chrysalis	

2. Metazoa

(*a*) *Turbellaria*

Stenostomum leucops

(*b*) *Rotatoria*

Philodina roseola
Rotifer vulgaris
Euchlanis dilatata

(*c*) *Gastrotricha*
Chaetonotus sp.*
(*d*) *Nematoda*
(*e*) *Annelida* (species undetermined)
Aeolosoma hemprichi
* Undetermined species.

3. On the Distribution of Fauna in Various Depths of Trickling Filters.—During the entire investigations a weekly record was made of the forms which were found in each depth of the filter. For several weeks a daily record was kept for each depth. Before applying the skim milk solution, tap water was passed through the filter for several days in order to make proper adjustments for even distribution of flow over the entire surface of each depth. Collections were made of the tap water effluent at the various levels in order to determine the forms present before starting the milk experiments. The organisms found in the filter during this period of washing were not abundant and in some of the samples several preparations were necessary to locate any organisms. In the supply tank and the first foot there were a few specimens of *Oxytricha*, *Vorticella*, *Bodo* and *Uronema*. These were found to be the common forms in the first four feet of the filter. In the fifth and sixth foot depths several additional forms were found. This could possibly be explained by the fact that the last two sections had been used in previous experiments, and the cysts of these genera were present.

(*a*) *Effect of Change of Rate on Fauna.*—In the course of experimental work the rate of application and concentration of waste was altered in order to observe the effects of this change on the incidence of fauna at various depths. The actual experimental work was started February 14, 1927. A 0.5 per cent solution of skim milk was applied at a rate of 800,000 gallons per acre per day (200 cc. per minute). The fauna which appeared in the various depths of the filter from February 15 to March 11, with a constant rate of flow and concentration of waste, are given in Table III.

TABLE III

FAUNA AT DIFFERENT DEPTHS OF A LATH FILTER RECEIVING 0.5 PER CENT SKIM MILK AT A RATE OF 800,000 GALLONS PER ACRE PER DAY

First Foot (Top)

**February 15*	*February 24*	*March 4*	*March 11*
Chilodon	Chilodon	Lionotus	Lionotus
Lionotus	Oxytricha	Vorticella	Vorticella
Oxytricha	Lionotus	Uronema	Oxytricha
Uronema	Uronema	Oxytricha	Rotifera
Stylonychia	Vahlkampfia	Cinetochilum	Podophrya
Vahlkampfia	Rotifera	Nematoda	Nematoda
Mastigamoeba	Aeolosoma	Rotifera	Stylonychia

* *Genera arranged according to abundance.*

Glaucoma	Podophrya	Podophrya	Aeolosoma
Amoeba	Amoeba	Amoeba	Glaucoma
	Bodo	Vahlkampfia	Amoeba
		Bodo	Vahlkampfia
			Chilodon
			Bodo

Second Foot

February 15	*February 24*	*March 4*	*March 11*
Stylonychia	Stylonychia	Stylonychia	Stylonychia
Lionotus	Lionotus	Cinetochilum	Chilodon
Vorticella	Cinetochilum	Uronema	Uronema
Uronema	Rotifera	Vorticella	Lionotus
Rotifera	Nematoda	Chilodon	Nematoda
Oxytricha	Euplotes	Lionotus	Rotifera
Amoeba	Oxytricha	Oxytricha	Arcella
Vahlkampfia	Aeolosoma	Rotifera	Bodo
Bodo	Vahlkampfia	Nematoda	Amoeba
	Amoeba	Aeolosoma	
	Bodo	Bodo	
		Amoeba	
		Vahlkampfia	

Third Foot

February 15	*February 24*	*March 4*	*March 11*
Stylonychia	Rotifera	Rotifera	Rotifera
Rotifera	Stylonychia	Cinetochilum	Cinetochilum
Chilodon	Vorticella	Stylonychia	Stylonychia
Nematoda	Chilodon	Chilodon	Nematoda
Lionotus	Lionotus	Aeolosoma	Aeolosoma
Uronema	Oxytricha	Chlamydophrys	Vahlkampfia
Bodo	Nematoda	Nematoda	Bodo
	Vahlkampfia	Vahlkampfia	Lionotus
	Bodo	Amoeba	Actinophrys
		Oxytricha	
		Actinophrys	

Fourth Foot

February 15	*February 24*	*March 4*	*March 11*
Chilodon	Rotifera	Cinetochilum	Cinetochilum
Lionotus	Chilodon	Rotifera	Stylonychia
Stylonychia	Stylonychia	Stylonychia	Rotifera
Vorticella	Lionotus	Lionotus	Vorticella
Oxytricha	Vorticella	Oxytricha	Lionotus
Vahlkampfia	Euplotes	Uronema	Nematoda
	Uronema	Vorticella	Chlamydophrys
	Vahlkampfia	Euplotes	Bodo
	Amoeba	Nematoda	Amoeba
	Actinophrys	Podophrya	Vahlkampfia
		Vahlkampfia	Arcella
		Actinophrys	Actinophrys
		Aeolosoma	
		Nematoda	

Fifth Foot

February 15	*February 24*	*March 4*	*March 11*
Chilodon	Chilodon	Rotifera	Rotifera
Lionotus	Rotifera	Lionotus	Vorticella
Rotifera	Vorticella	Chilodon	Chilodon
Euplotes	Lionotus	Vorticella	Lionotus
Stylonychia	Euplotes	Euplotes	Stylonychia
Oxytricha	Stylonychia	Bodo	Euplotes
Nematoda	Oxytricha	Stylonychia	Oxytricha
Vahlkampfia	Amoeba	Nematoda	Aeolosoma
	Bodo	Vahlkampfia	Vahlkampfia
	Cinetochilum	Oxytricha	Arcella
		Amoeba	Bodo
		Aeolosoma	Amoeba
		Arcella	

Sixth Foot

February 15	*February 24*	*March 4*	*March 11*
Stylonychia	Rotifera	Lionotus	Rotifera
Lionotus	Vorticella	Rotifera	Lionotus
Bodo	Lionotus	Amoeba	Vorticella
Uronema	Bodo	Vorticella	Amoeba
Oxytricha	Amoeba	Nematoda	Arcella
Vahlkampfia	Stylonychia	Aeolosoma	Cinetochilum
	Euplotes	Arcella	Stylonychia
	Oxytricha	Stylonychia	Vahlkampfia
	Vahlkampfia	Vahlkampfia	Bodo
		Bodo	Euplotes
		Chilodon	Oxytricha
			Vahlkampfia

On March 14, 1927, the rate of flow of the milk solution was raised to 1,600,000 gallons per acre per day (or 400 cc. per minute). This increase doubled the rate of filtration but the concentration was not changed. Immediately following the increase in rate of flow, there was a decided change in the fauna. It was noted that some genera increased in number of individuals per cubic centimeter, and others decreased. There was also a migration of some types within the filter. Counts made from materials taken from all six levels showed a decided increase in number of organisms present.

One striking example of the changes which took place may be explained by following the incidence of the genus *Colpoda* and *Uronema*. Before the rate of flow was raised the genus *Colpoda* had never been found in any part of the filter. Shortly after the changes was made this genus became the predominating group of organisms. *Uronema*, present only in very limited numbers before the increase in rate of flow, increased almost as rapidly as *Colpoda*. There were several other genera which showed a decided disturbance, but these genera were all in the large class *Ciliata*.

The ciliates showed more variation in every change which was made. The rhizopods, flagellates and metazoa were more stable and showed less

TABLE IV

FAUNA AT DIFFERENT DEPTHS OF A LATH FILTER RECEIVING 0.5 PER CENT SKIM MILK AT 1,600,000 GALLONS PER ACRE PER DAY

First Foot

March 20	*March 28*	*April 5*	*April 25*
Colpoda	Colpoda	Uronema	Colpoda
Uronema	Uronema	Colpoda	Chilodon
Bodo	Lionotus	Bodo	Bodo
Lionotus	Bodo	Lionotus	Lionotus
Chilodon	Amoeba	Chilodon	Cinetochilum
Stylonychia	Cinetochilum	Cinetochilum	Amoeba
Cinetochilum	Chilodon	Amoeba	Dimastigamoeba
Glaucoma	Glaucoma	Chlamydophrys	Vahlkampfia
Chlamydophrys	Rotifera	Rotifera	Chlamydophrys
Rotifera	Dimastigamoeba	Vorticella	Vorticella
Stenostomum	Vahlkampfia	Glaucoma	Glaucoma
Arcella	Arcella	Pleuronema	Rotifera
Podophrya	Chlamydophrys	Vahlkampfia	Opercularia
Trepomonas	Trepomonas	Opercularia	Nematoda
Vahlkampfia	Vampyrella	Nematoda	Oicomonas
Nematoda	Nematoda	Prodophrya	Pleuronema
Vampyrella	Oicomonas	Oicomonas	Centropyxis
Amoeba	Euplotes	Euplotes	Euplotes
Euplotes	Tetramitus	Centropyxis	Pedophrya
Oicomonas			Tetramitus

Second Foot

March 20	*March 28*	*April 5*	*April 25*
Colpoda	Colpoda	Colpoda	Cinetochilum
Uronema	Cinetochilum	Cinetochilum	Colpoda
Cinetochilum	Lionotus	Lionotus	Lionotus
Lionotus	Dimastigamoeba	Bodo	Chilodon
Vorticella	Uronema	Chilodon	Glaucoma
Chilodon	Vorticella	Uronema	Vorticella
Stylonychia	Chilodon	Vorticella	Amoeba
Amoeba	Vahlkampfia	Amoeba	Dimastigamoeba
Vahlkampfia	Amoeba	Pleuronema	Vahlkampfia
Podophrya	Chlamydophrys	Arcella	Centropyxis
Actinophrys	Arcella	Euplotes	Pleuronema
Arcella	Pleuronema	Stenostomum	Rotifera
Stenostomum	Euplotes	Euglypha	Euplotes
Oxytricha	Stenostomum	Nematoda	Euglypha
Euglypha	Bodo	Rotifera	Mastigamoeba
Bodo	Euglypha	Tetramitus	Nematoda
Nematoda	Nematoda		Opercularia
Rotifera	Rotifera		Actinophrys
	Tetramitus		Stenostomum
			Bodo

Third Foot

March 20	*March 28*	*April 5*	*April 25*
Uronema	Colpoda	Colpoda	Colpoda
Cinetochilum	Uronema	Cinetochilum	Lionotus
Colpoda	Cinetochilum	Bodo	Cinetochilum
Lionotus	Bodo	Uronema	Uronema
Bodo	Amoeba	Stylonychia	Stylonychia
Stylonychia	Vahlkampfia	Vorticella	Amoeba
Podophrya	Nematoda	Amoeba	Vorticella
Nematoda	Chlamydophrys	Stenostomum	Euglypha
Vahlkampfia	Arcella	Nematoda	Chlamydophrys
Arcella	Euglypha	Euglypha	Podophrya
Euglypha	Peranema	Peranema	Stenostomum
Cercobedo	Pleuronema	Chlamydophrys	Rotifera
Stenostomum	Stenostomum	Podophrya	Arcella
Chilodon	Vorticella	Arcella	Centropyxis
Vorticella	Podophrya	Actinophrys	Rotifera
Pleuronema	Oxytricha	Rotifera	Pleuronema
	Rotifera	Pleuronema	Tetramitus

Fourth Foot

March 20	*March 28*	*April 5*	*April 25*
Uronema	Colpoda	Cinetochilum	Colpoda
Colpoda	Uronema	Colpoda	Cinetochilum
Cinetochilum	Lionotus	Lionotus	Uronema
Vorticella	Vorticella	Uronema	Lionotus
Lionotus	Cinetochilum	Cinetochilum	Vorticella
Amoeba	Amoeba	Vorticella	Stylonychia
Vahlkampfia	Vahlkampfia	Stylonychia	Oxytricha
Rotifera	Oxytricha	Oxytricha	Euplotes
Stenostomum	Stenostomum	Peranema	Peranema
Pleuronema	Peranema	Arcella	Arcella
Arcella	Pleuronema	Chlamydophrys	Chlamydophrys
Euglypha	Euglypha	Rotifera	Rotifera
Peranema	Arcella	Opercularia	Opercularia
Actinophrys	Actinophrys	Cyclidium	Cyclidium
Podophrya	Rotifera	Actinophrys	Stenostomum
Chlamydophrys	Chlamydophrys	Stenostomum	Nematoda
Bodo	Opercularia	Nematoda	Amoeba
Nematoda	Cyclidium	Amoeba	Vahlkampfia
Tetramitus	Pleurotricha	Vahlkampfia	Tetramitus
	Nematoda	Dimastigamoeba	
	Dimastigamoeba	Tetramitus	

Fifth Foot

March 20	*March 28*	*April 5*	*April 25*
Colpoda	Uronema	Colpoda	Lionotus
Uronema	Colpoda	Chilodon	Cinetochilum
Lionotus	Lionotus	Lionotus	Colpoda
Chilodon	Chilodon	Cinetochilum	Stylonychia
Vorticella	Cinetochilum	Stylonychia	Chilodon

Stylonychia	Vorticella	Amoeba	Amoeba
Vahlkampfia	Stylonychia	Vahlkampfia	Arcella
Amoeba	Amoeba	Arcella	Euglypha
Chlamydophrys	Chlamydophrys	Nematoda	Opercularia
Arcella	Arcella	Rotifera	Stenostomum
Nematoda	Nematoda	Stenostomum	Actinophrys
Stenostomum	Stenostomum	Actinophrys	Oxytricha
Rotifera	Rotifera	Oxytricha	Rotifera
	Tetramitus	Tetramitus	Nematoda

Sixth Foot

March 20	*March 28*	*April 5*	*April 25*
Chilodon	Chilodon	Colpoda	Chilodon
Colpoda	Colpoda	Chilodon	Colpoda
Lionotus	Vorticella	Vorticella	Vorticella
Vorticella	Lionotus	Lionotus	Vahlkampfia
Nematoda	Rotifera	Vahlkampfia	Rotifera
Rotifera	Nematoda	Rotifera	Nematoda
Stenostomum	Stenostomum	Stenostomum	Stenostomum
Amoeba	Vahlkampfia	Pleurotricha	Amoeba
Vahlkampfia	Amoeba	Amoeba	Actinophrys
Actinophrys	Podophrya	Podophrya	Podophrya
Podophrya	Pleurotricha	Amoeba	Tetramitus
Tetramitus	Euplotes	Tetramitus	

variation. Table IV gives the records from March 16 to April 25, 1927, showing the genera, in order of abundance, after the rate of flow was raised from 800,000 to 1,600,000 gallons per acre per day.

(*b*) *Effect of Change of Concentration on Fauna.*—On June 6, 1927, the concentration of the milk solution was raised to 1.0 per cent, and the rate of flow was lowered to 800,000 gallons per acre per day or 200 cc. per minute. Shortly after the change the top level started to slough. While sloughing was in progress the metazoa increased, but as the sloughing ceased the metazoa decreased slowly and the protozoa increased, this taking place only in the sections which were sloughing. It was found that some of the animal groups migrated toward the bottom after the change. The genus *Colpoda* decreased rapidly in number of organisms per cubic centimeter and in about two weeks this group had disappeared. Forms found are listed in Table V.

On June 27, 1927, the concentration of the waste was raised from 1 to 2 per cent but the rate of flow was not altered. A few days after the change was made the protozoa decreased and the rotifers and nematodes increased in number of individuals per unit volume of sample. The increase was quite noticeable for some time and the rotifers and nematodes became quite abundant. The various groups of protozoa did not disappear but the number of individuals fell far below the average. Table VI shows the forms which were found in the various depths of the filter.

TABLE V

FAUNA AT DIFFERENT DEPTHS OF A LATH FILTER RECEIVING 1.0 PER CENT SKIM MILK AT 800,000 GALLONS PER ACRE PER DAY

June 18, 1927

First Foot	*Second Foot*	*Third Foot*
Cinetochilum	Uronema	Uronema
Cyclidium	Cyclidium	Rotifera
Uronema	Rotifera	Cyclidium
Rotifera	Nematoda	Nematoda
Nematoda	Bodo	Cinetochilum
Bodo	Aeolosoma	Peranema
Aeolosoma	Stenostomum	Vorticella
Chlamydophrys	Vahlkampfia	Aeolosoma
Vahlkampfia	Centropyxis	Vahlkampfia
Peranema	Arcella	Arcella
Centropyxis	Euglypha	Centropyxis
Lionotus	Chlamydophrys	Euglypha
Podophrya	Podophrya	Chlamydophrys
Amoeba	Amoeba	Stenostomum
Stenostomum	Euplotes	Amoeba
Euplotes	Gastrotricha	Bodo
Gastrotricha	Lionotus	Lionotus
Chilodon	Vampyrella	Gastrotricha
Glaucoma		Actinophrys
Vampyrella		

Fourth Foot	*Fifth Foot*	*Sixth Foot*
Lionotus	Uronema	Vorticella
Peranema	Vorticella	Rotifera
Vorticella	Rotifera	Nematoda
Euglypha	Nematoda	Gastrotricha
Centropyxis	Amoeba	Chlamydophrys
Arcella	Vahlkampfia	Bodo
Rotifera	Arcella	Amoeba
Nematoda	Aeolosoma	Vahlkampfia
Aeolosoma	Lionotus	Stenostomum
Uronema	Chilodon	Aeolosoma
Cinetochilum	Cinetochilum	Chilodon
Cyclidium	Bodo	Uronema
Bodo	Cyclidium	Cinetochilum
Amoeba	Euplotes	Arcella
Vahlkampfia	Euglypha	Euplotes
Podophrya	Centropyxis	
Paramecium		
Stenostomum		

Discussion

1. **Protozoa.**—The rhizopods were fairly abundant during the entire investigation of the experimental trickling filter. Samples examined

TABLE VI

FAUNA AT DIFFERENT DEPTHS OF A LATH FILTER RECEIVING 2.0 PER CENT SKIM MILK AT 800,000 GALLONS PER ACRE PER DAY

July 28, 1927

First Foot	*Second Foot*	*Third Foot*
Chilodon	Cinetochilum	Rotifera
Rotifera	Rotifera	Lionotus
Cinetochilum	Opercularia	Nematoda
Bodo	Vorticella	Euglypha
Nematoda	Cyclidium	Centropyxis
Vorticella	Uronema	Bodo
Uronema	Bodo	Cinetochilum
Pleuronema	Vahlkampfia	Vorticella
Amoeba	Cercobodo	Uronema
Cyclidium	Monas	Oxytricha
Opercularia	Nematoda	Chilodon
Arcella	Anthophysa	Amoeba
Vahlkampfia	Arcella	Vahlkampfia
Chlamydophrys	Stenostomum	Opercularia
Centropyxis	Aeolosoma	Aeolosoma
Glaucoma	Chlamydophrys	Stenostomum
	Centropyxis	

Fourth Foot	*Fifth Foot*	*Sixth Foot*
Rotifera	Rotifera	Rotifera
Nematoda	Gastrotricha	Gastrotricha
Euglypha	Vorticella	Nematoda
Lionotus	Chlamydophrys	Bodo
Vahlkampfia	Nematoda	Aeolosoma
Vorticella	Amoeba	Vorticella
Stenostomum	Centropyxis	Opercularia
Glaucoma	Bodo	Cyclidium
Centropyxis	Stylonychia	Trepomonas
Bodo	Opercularia	Arcella
Chlamydophrys	Stenostomum	Vahlkampfia
Arcella	Paramecium	Amoeba
Stylonychia	Uronema	Paramecium
Paramecium		

from any portion of the filter contained some of the smaller forms, and if these samples were left standing, or cultures made, large numbers appeared. *Vahlkampfia limax, Vahlkampfia albida, Dimastigamoeba gruberi* and of the shelled forms *Euglypha alveolata, Arcella vulgaris* and *Chlamydophrys* were the most common. The shelled rhizopods were found to be more numerous in the three upper depths of the filter. *Dimastigamoeba gruberi* was the most common species of this group. This species appeared during the period of washing with tap water and could be found at almost any depth during the entire period of investigation. C. W. Wilson (1915) listed this same species with the common coprozoic amoebae. Lackey

(1925) found the same amoeba in Imhoff tanks. Flagellated stages were never observed directly from the filter but did appear if the samples were left standing in the laboratory.

Amoeba villosa, a large amoeba, distinguished by its peculiar structure, was on several occasions found to be quite common in the first and second foot of the filter. Leidy (1879) and Shaeffer (1926) list this species as a rare form in the United States. It has never been listed with the protozoa of Imhoff tanks or sprinkling filter beds.

The flagellates were on two occasions the most common forms. None of the larger forms were found well established in any part of the filter, but were fairly abundant in the first and second foot. This was true of *Peranema* and *Distigma*, but the latter form was abundant only once during the investigation. *Peranema* was considered a common form not because of large numbers at any time but because almost all samples contained a few specimens. *Trepomonas agilis*, a small flagellate which Lackey (1925) considered as the most important protozoon in Imhoff tanks, was not abundant at any time in the trickling filter. Lackey states that this species increased when the tanks foamed or were working poorly. In the writer's observations with the trickling filter *Trepomonas agilis* never appeared in large numbers. The number of individuals per cubic centimeter did increase slightly during sloughing of the four upper depths but this was also the case with many other species.

The small flagellates were common in all depths of the filter and also in the supply tank. The genus *Bodo* was by far the most common and samples from any part of the filter contained a large number of individuals. *Cercobodo* was the common flagellate of the second and third depths, but was far inferior to the genus *Bodo* in other portions of the filter. These smaller forms varied with the rate of flow and concentration of waste more markedly than the small rhizopods.

The ciliates were considered most important because of the large number of genera which were found to be common during the period of investigation. For a time the two genera *Colpoda* and *Uronema* were the predominating forms of the entire filter. Lackey (1925) found only four genera of the class *Ciliata* to be common in the Imhoff tanks. Hausman (1923) found that the ciliates were not as common in trickling filters as the other protozoan groups. In our trickling filter there was a decided fluctuation among the individual species in this group. After a change in rate of flow or concentration of waste, some of the ciliates decreased markedly while others increased. The ciliates as a whole did not fluctuate any more than the other groups.

The fact that most all the ciliates described are bacteria feeders would tend to make them very important in affecting bacterial action.

2. **Metazoa.**—The metazoa were quite common in the various depths

of the filter, but the number of individuals varied quite markedly. These organisms were more abundant in the lower depths, but a few were almost always found in the upper two feet.

The free-living nematode worms were found in all parts of the filter and in the dosing tank. These small animals were usually more abundant in the lower portion of the filter. Hausman states that the nematode worms were very important in connection with sloughing of the filter films. The nematodes of the trickling filter increased at the beginning of sloughing and decreased after sloughing.

The rotifers were found in all depths of the filter and it was noticed that these organisms were very sensitive to slight changes in rate of flow and concentration of the waste.

The annelids were represented by only one genus, *Aeolosoma*. During the first part of this work *Aeolosoma* was found to be quite abundant in the lower portions of the filter. After the increase in rate of flow of the waste material this form disappeared and was never found again in any portion of the filter. On the other hand *Stenostomum*, a member of the *Turbellaria*, became quite abundant and persisted.

The organisms listed under the metazoa were not so numerous as the protozoa, but their size and feeding habits make them very important. The worms may play some part in the sloughing of the films. The rotifers and some of the worms are known to feed on the protozoa, and this has been observed on several occasions during this investigation. It was also noted that most of the metazoa were located in the lower depths of the filter and in these parts the protozoa were not as numerous. Conversely in the upper levels where the metazoa were not common the protozoa were very abundant.

Summary

1. This investigation was conducted for the purpose of determining the fauna of an experimental trickling filter operating under partially controlled conditions, and to note the distribution of the fauna in the various depths.

2. The experimental trickling filter had both a protozoan and metazoan fauna.

3. Three classes of protozoa were represented: *Sarcodina*, *Mastigophora* and *Infusoria*.

4. Ten species of the class *Sarcodina*, nine species of the class *Mastigophora* and fourteen species of the class *Infusoria* were found to be common forms; and in addition nineteen other forms were observed.

5. *Rotatoria*, *Nematoda* and *Annelida* were the important groups of the metazoa.

6. With an increase of metazoa in any section of the filter there was

a decrease in protozoa and vice versa. This was noted especially during the sloughing period of the various depths. The metazoa increased before sloughing and decreased after the period of sloughing had ended. The protozoa decreased before the sloughing period and increased after sloughing was completed.

7. There was a fluctuation of protozoa and metazoa with changes in rate of flow, concentration of applied waste, and during the period of sloughing.

8. The hydrogen-ion concentration of the samples ranged from 6.7 to 8.0.

The authors wish to express their indebtedness to Dr. Max Levine, Professor of Sanitary Bacteriology at Iowa State College and Bacteriologist of the Iowa Engineering Experiment Station, who has made it possible to conduct this work, for his valuable criticism and suggestions; also to Harry E. Gorseline for the data on the hydrogen-ion concentration of the effluents.

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Effect of Age of Fresh Solids on Digestion[1]

BY H. HEUKELEKIAN[2]

It is at present considered to be good practice not to allow sewage solids to get septic before they are introduced into separate sludge digestion tanks. Imhoff tanks have an advantage in this respect since settling and seeding take place more or less simultaneously. If the solids are allowed to become septic in a settling tank foul odors increase and some of the liquefied material as well as the solid particles are carried out in the effluent. Furthermore, the longer the settled solids are allowed to stand without seeding the more lime is required to correct the reaction. Although these facts are well established the actual effect of the septic solids on subsequent digestion is not fully known. It is generally assumed that the accumulated acidity retards digestion.

It has been shown that digestion consists of two phases, liquefaction and gasification, probably with distinctly different types of flora. If the material has to be liquefied before it can be gasified the rate of reaction of the first process will determine the rate of the second. For rapid digestion, therefore, instead of trying to accelerate the rate of gasification we should speed up liquefaction. The optimum conditions for liquefaction may be different than those for gasification. The addition of ripe sludge rich in gasifying organisms might not be of value to liquefaction. Furthermore, there is some evidence that liquefaction may proceed under more acid conditions. In the acid stage there is an accumulation of liquefied substances, mainly fatty acids, which on neutralization gasify readily. Thus it seems probable that septicization of the solids might even prove beneficial for subsequent digestion.

To determine whether septic solids actually shorten or lengthen the period of subsequent digestion the following experiments were carried out:

1. Septic solids of various ages were seeded without any further treatment.
2. Septic solids of various ages were limed and seeded.
3. Supernatant liquid of the septic solids was drawn off before seeding.

Methods

The fresh solids used in these experiments were collected from the Plainfield plant by hanging pails in the settling tank for 24 hours. The ripe sludge was obtained from the separate sludge digestion tanks. Equal quantities of the fresh solids were distributed into different bottles and kept in the incubator. At definite intervals the septic solids were seeded

[1] *Journal Series Paper of the New Jersey Agricultural Experiment Station, Department of Sewage Disposal.*

[2] *Research Bacteriologist, Department of Sewage Disposal.*

with ripe sludge in the ratio of 2:1 (2 of fresh solids to 1 of ripe sludge on the basis of volatile matter). No allowance was made for the reduction of volatile matter during the period of septic digestion but the seeding ratio was based on the original quantity of fresh solids. The reduction of volatile matter during the periods of septicization employed would not be appreciable.

Daily gas measurements, solids and ash determinations at the beginning and end of digestion were made. Gas measurements were taken after the fresh solids were seeded.

Results

Digestion at 80° F.—The results of the first series, with digestion of septic solids at 80° F., are given in Figures 1 and 2. The figures represent the daily volume of gas produced per gram of the original volatile solids, after seeding. The solids were septicized for a period of 16 days. From the figures it is not possible to detect any significant differences in the rate of digestion. In fact the curves are strikingly similar. The rate of gasification in the mixture with strictly fresh solids as well as with solids septicized for 12 days reached the peak in 13–14 days. With solids 16 days old the peak was reached in 11 days.

TABLE I

EFFECT OF THE AGE OF FRESH SOLIDS ON THE LENGTH OF DIGESTION TIME AND THE GAS YIELD AT 80° F.

Age of Fresh Solids (Days)	Gasification Completed in (Days)	Complete Digestion Septic and Seeded (Days)	Gas,[1] Cc.
0	23–24	23–24	622
2	24–25	26–27	620
4	24–25	28–29	582
6	25–26	31–32	597
9	23–24	32–33	524
12	22–23	34–35	500
16	22	38	422

[1] Per gram of the original raw volatile matter.

In Table I are given the days required to complete gasification after seeding, as well as the total digestion time, including the septic period and the period after seeding. Gasification was considered complete for practical purposes when the daily volume of gas evolved fell to a value of 6 cc. per gram of volatile matter. On this basis the differences in time required to complete gasification are within 1 or 2 days and should be considered as within experimental error. In short, it seems that the time required to complete gasification after seeding is the same whether the solids are strictly fresh or septicized for 16 days, but the total time required is increased by the period of septicity.

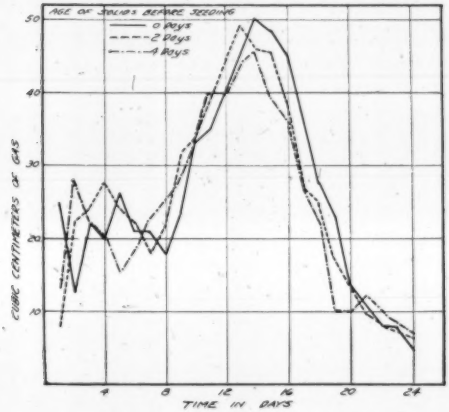

FIG. 1

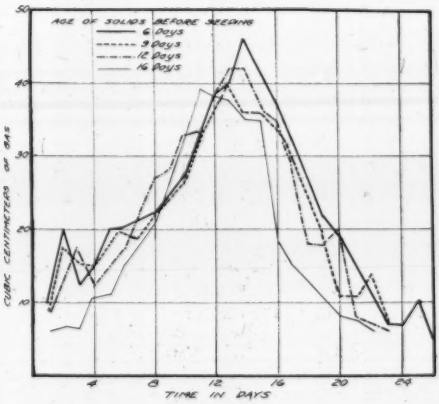

FIG. 2

Figs. 1 and 2.—Gas Production at 80° F. from Seeded Mixtures of Solids Aged for Various Periods (Cc. Gas per Gram of Original Raw Volatile Matter).

In Table I are also given the gas yields per gram of volatile matter in the original fresh solids. The yield progressively decreases with the age of solids.

Digestion at 70° F.—It was thought that since 80° F. is the optimum

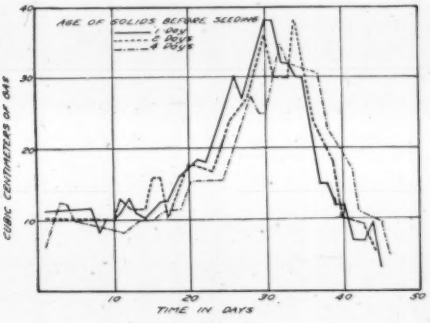

FIG. 3.

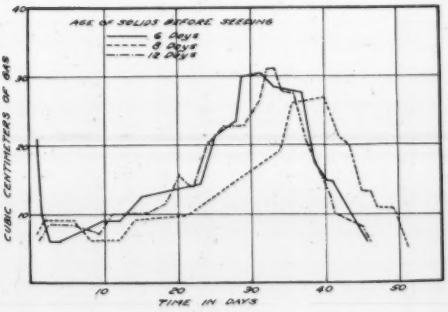

FIG. 4.

Figs. 3 and 4.—Gas Production at 70° F. from Seeded Mixtures of Solids Aged for Various Periods (Cc. Gas per Gram of Original Raw Volatile Matter).

for digestion differences in rate of digestion due to septicization might not be so noticeable as they would be at a less favorable temperature. Accordingly a similar series was run at 70° F. The results are represented in Figures 3 and 4. The longest period of septicization in this series was 12 days.

There are no significant differences in the rate of digestion of the different mixtures except for the one with septic solids eight days old. The peak of gasification in this mixture was attained five or six days later than for solids six or twelve days old. In Table II are given the days required from the time of seeding to the end of gasification, as well as complete digestion time (septic and seeded) and the yield of gas. As in the previous series the time to complete gasification was not materially changed by ageing the solids except in the case of solids eight days old. A similar lengthening of the time to complete gasification is to be noted in the previous series where the solids six days old required two or three more days than all others.

TABLE II

EFFECT OF THE AGE OF SOLIDS ON THE LENGTH OF DIGESTION TIME AND THE GAS YIELD AT 70° F.

Age of Solids (Days)	Gasification Completed in (Days)	Complete Digestion Septic and Seeded (Days)	Gas,[1] Cc.
1	44–45	45–46	773.6
2	44	46	764.1
4	45–46	49–50	758.4
6	46	52	737.1
8	50–51	58–59	720.7
12	45–46	57–58	704.4

[1] Per gram of the original raw volatile matter.

The yield of gas was higher in this series than in the previous one. The percentage reduction in the gas yield due to septicization was different in the two series. For a 12-day period 20% less gas was obtained in the first series while the gas yield was reduced only 9% in the second. The reduction in the volume of gas due to the digestion of septic solids cannot be explained on the basis of gas liberated during the septic periods of digestion. Fresh solids incubated unseeded for 12 days produced only 10 cc. of gas per gram of volatile matter.

Effect of Lime.—It was considered of interest to determine whether any beneficial effects would result by allowing the solids to become septic and then correcting the acidity produced by the addition of lime before seeding. If the optimum pH for liquefaction is in the acid range and for gasification in the alkaline, then beneficial results should be obtained by allowing the solids to become septic before liming and seeding. In order to study this possibility the fresh solids at the end of definite periods of ageing at 80° F. were treated with lime until a pH value of 6.8–7.0 was obtained. They were then seeded and reincubated.

The results obtained are so similar to those in the previous series that the individual curves will not be presented. The summary of the results are given in Table III. Gasification was completed within 25–26 days with the exception of solids 15 and 20 days old, which required 27 and 29

days, respectively. The total period of digestion, including the septic period, increased with the age of solids. The gas yield decreased with the age of solids. The solids 11 days old gave 13% less gas than the solids 1 day old after seeding. No significant differences were noted in the reduction of volatile matter of the mixtures. Increasing amounts of lime were required to bring the pH value up to 6.8–7.0. The solids 11 days old required 50% more lime than the fresh solids.

TABLE III

EFFECT OF AGE OF FRESH SOLIDS ON DIGESTION AT 80° F. (LIMED SERIES)

Age of fresh solids, days	1	2	4	7	11	15	20
Gasification completed, days	25	25	26	26	25	27	29
Complete digestion septic and seeded, days	26	27	30	33	36	42	49
Gas, cc.[1]	800	760	785	725	695	680	715
% reduction of volatile matter	39.0	37.5	41.7	40.8	39.0	37.5	34.3
pH of fresh solids	5.6	5.6	5.6	5.4	5.3	5.3	5.3
Lime added, g.	1.86	2.40	2.40	3.36	2.88	3.18	4.32
pH fresh solids adjusted to	6.8	7.0	6.8	7.0	6.9	6.8	7.0

[1] Per gram of the original raw volatile matter.

In general, then, the addition of lime to the septic solids did not bring about any material improvement in the digestion of the mixtures. The results are similar to the digestion of the septic solids without lime.

Effect of Drawing Off the Supernatant Liquid of the Septic Solids.—It seemed probable that the same purpose could be achieved by drawing off the liquid instead of liming it. Hence at the end of different periods of incubation the supernatant liquid of the fresh solids was drawn off and the remaining solids seeded with ripe sludge in the ratio of 2:1. Incubation was at 80° F. The results are summarized in Table IV. Gasification was completed in 19–20 days with the exception of the solids 20 days old,

TABLE IV

EFFECT OF AGE OF FRESH SOLIDS ON DIGESTION AT 80° F.

(SUPERNATANT LIQUID WITHDRAWN)

Age of fresh solids, days	2	4	8	12	20
Gasification completed, days	19	19	19	20	22
Total period of digestion (including septic period), days	21	23	27	32	44
Gas, cc.[1]	665	640	590	575	590
% volatile matter reduction in the mixture	39.4	36.4	31.4	31.4	35
% solids in septic solids after drawing off the supernatant liquid	6.03	6.47	9.06	10.8	10.9

[1] Per gram of the original raw volatile matter.

which required 22 days. Septicization up to 12 days again did not prolong the period of gasification. A 13% reduction in the volume of gas was obtained by septicizing for 12 days. The concentration of the solids increased by 50% during the 12 days of septicization.

That the withdrawal of liquid aids the digestion of unseeded solids is shown in Table V. The withdrawal of liquid in the digestion of unseeded solids is beneficial. In the properly seeded solids the acidity produced is neutralized by the ripe sludge.

TABLE V

DIGESTION OF UNSEEDED SEPTIC SOLIDS

	After One Month	
	Reduction of Volatile Matter, %	pH
Fresh solids, liquid not drawn off	13.5	5.6
Septic for 1 week before drawing off liquid	20.3	7.0
Septic for 2 weeks before drawing off liquid	15.6	6.0

Discussion

It seems evident from the foregoing results that septic solids digest just as rapidly as fresh solids, if properly seeded. Since these experiments were undertaken (in April, 1928) Fair and Klein[1] have published the results of similar experiments which did not show any "regular and progressive deterioration of the digestibility of sewage solids that are left unseeded." It is difficult to explain why, for instance, sewage solids 2 days old should digest at a considerably slower rate than solids 6 or 17 days old. With the Plainfield fresh solids no such inconsistencies were noticed.

Nevertheless, it seems unlikely that the rate of gasification should be independent of the age of solids. Such conditions would indicate that even liquefaction does not occur rapidly at a pH value of 5.2. Septicization at a higher pH value might have given different results. It is further possible that conditions prevailing in seeded mixtures are optimum both for gasification as well as liquefaction. Hence from the standpoint of the total time of digestion the period of septic digestion can be considered as wasted.

The maximum period of septicization in these experiments did not exceed 20 days. It is difficult to predict what would happen if solids were septicized for longer periods. From the standpoint of desirable concentration of fresh solids an 8-day storage period is sufficiently long. During this period a 50% increase in the density of the solids might be expected. The total digestion time (including time wasted in the septic storage process) is increased by 30% at 70° F. There might thus be an advantage

[1] THIS JOURNAL, **1**, 14–19 (1928).

in storing the sludge in a tank for about a week before pumping it into the separate digestion tank. If this be done the supernatant liquid must be treated further. Returning it to the settling tank will not solve the problem because most of the solids are liquefied or colloidal and will not settle. Adequate treatment of this liquid might be obtained by some kind of oxidation device. If secondary treatment is by trickling filters which are not overloaded, a satisfactory treatment may be obtained, although odors may increase to a certain extent. The liquid might also be treated by partial aeration.

Liming of septic solids did not materially reduce the digestion time after seeding. Although the acidity of settled solids increased with storage, when properly seeded no retardation took place even without addition of lime. With optimum temperature and seeding conditions the adverse effect of acidity was soon overcome. Thus temperature and seeding are more important factors than the treatment of the solids. Drawing off the liquid had a more favorable effect on the digestion than liming the septic solids.

The yield of gas decreased with the age of fresh solids. With one exception the decrease in the gas yield for solids 12 days old was 9–13 per cent. Removal of sludge liquor did not change this result. The reduction in the yield of gas cannot be explained by correction for the gas evolved during the period of septicization because very small quantities of gas are produced by fresh solids during such a short period. The explanation seems to be that during the period of septicization a part of the material which would normally produce gas is converted into liquefied solids which on seeding do not produce any gas. Thus we seem to arrive at the conclusion that liquefaction produces a partly stable material not all of which need necessarily gasify. Furthermore, it indicates that the processes in the digestion of seeded and unseeded solids are not strictly comparable.

Conclusions

1. Ageing sewage solids up to two weeks did not cause an appreciable retardation of digestion when the solids were properly seeded and incubated at 70° or 80° F.

2. The period of septic storage should be considered as wasted and added to the time required for digestion after seeding.

3. The gas yields from seeded mixtures of septic solids were reduced considerably below the yields from seeded fresh solids. About 9–13% reduction in the yield of gas was obtained from solids that were aged for 12 days.

4. The time required to complete gasification after seeding was the same whether the septic solids were neutralized with lime or not.

5. The time required to complete gasification after seeding was somewhat shorter when the supernatant liquid of the septic solids was drawn off.

6. During an 8-day storage period 50% increase in the density of the fresh solids took place. The increase in the total digestion time of seeded 8-day old solids at 70° F. was only 30 per cent.

Sewage Works Operation

Syracuse Sewage Treatment Works Summary of Four Years' Operating Experience

By Glenn D. Holmes[1] and W. P. Gyatt[2]

Conspectus.—This paper describes briefly the main plant of the Syracuse Sewage Treatment Works and presents operating and cost data covering the period since its completion. Treatment comprises screening, grit removal and plain sedimentation in tanks equipped with Dorr clarifiers for frequent sludge removal. The tank effluent is discharged without further treatment into deep water of Lake Onondaga. The sludge is pumped about 2 1/3 miles through a small force main, and disposed of by burial in the lime wastes of the Solvay Process Company. The sewage is pumped to the sedimentation tanks following degritting and screening. Analyses of the crude sewage, removal of suspended solids and the quantities of screenings, grit, scum and sludge are tabulated and summarized.

General Description, Sewer System.—The greater part of the city of Syracuse has a combined system of sewers; outlying tracts and recently annexed territory have separate sewers. The population of Syracuse in 1928 was approximately 210,000 of which 180,000, or 85.7 per cent, are estimated to be connected with the main treatment plant located near the lake front on Hiawatha Street. Syracuse has several small treatment plants, serving districts outside the main drainage system, which are not included in this discussion.

Intercepting sewers, paralleling the water courses of Onondaga Creek and Harbor Brook, convey the sewage to the treatment plant. The plant was designed to treat a dry weather flow of 27.5 m. g. d. estimated for 1940, and twice this quantity or 55.0 m. g. d. during storm periods. The intercepting sewers were designed for a future population of 400,000. Their combined capacity is about 130 m. g. d. These sewers are now utilized to full capacity during heavy precipitation, at which time flows in excess of 55 m. g. d. are bypassed at the plant to the lake.

[1] *Chief Engineer of the Syracuse (N. Y.) Intercepting Sewer Board and Supervising Engineer for the Bureau of Sewage Disposal. The duties of the Board include: design and construction of intercepting and trunk sewers; sewage treatment and flood prevention works; the investigation and preparation of plans for other related projects within the metropolitan area of Syracuse.*

[2] *Superintendent, Bureau of Sewage Disposal, Department of Public Works. In charge of operation and maintenance of the several treatment plants, pumping stations, and intercepting sewer systems.*

Experimental Station Method of Treatment and Disposal Adopted

Previous to the World War, general plans had been prepared for Imhoff tank and sprinkling filter treatment. A site was purchased about three miles from the city, well isolated and favorably located for this type of treatment. Application to the U. S. Capital Issues Committee for permission to issue bonds for construction was refused and this work was necessarily held in abeyance.

Prices for materials and labor soon increased to such an extent that it became desirable to devise a suitable method of treatment which could be installed and operated at less cost. A small experimental station was authorized for the purpose of determining the character of Syracuse sewage and ascertaining the degree of purification attainable with various methods of treatment.

Routine work at the station included operation of several types of sedimentation tanks, aerated filters and an activated sludge unit. Various methods of dewatering and disposing of sludge were investigated. Many analyses were made of the oxygen content of the water in streams and Onondaga Lake. In determining the economy which might be effected in the use of compressed air for activated sludge treatment, sedimentation for short detention periods was investigated in a small radial-flow tank equipped with a Dorr mechanism. It was found that a high percentage of removal of total suspended solids was obtained in a comparatively short period, when decomposition was prevented by frequent sludge removal.

As a result of the investigation conducted at this demonstration plant, the writer recommended that treatment of Syracuse sewage should include sedimentation in tanks equipped for continuous or frequent sludge removal and disposal of the tank effluent in deep water of Lake Onondaga; disposal and sterilization of the sludge by burial in the lime wastes of the Solvay Process Company.

These recommendations did not at first meet with the approval of the state authorities, and Metcalf & Eddy, Consulting Engineers, were employed to review the studies of the Board and to make such other investigations as they deemed necessary. Their report stated: "The sedimentation project is practical; will accomplish all that is necessary and can be adopted without fear of creating objectionable conditions in the vicinity of the plant or elsewhere. . . . This method will prove adequate for at least 20 years and may be sufficient for a much longer period. . . . Complete treatment in Imhoff tanks . . . and trickling filters . . . is unnecessary, . . . a saving of $1,500,000 can be affected. . . . Disposing of the sludge by mixing it with the industrial wastes . . . is unique and will prove highly effective. . . ."

Effect of Detention Period on Removal of Suspended Solids in Sedimentation Tanks

Previous to the preparation of contract drawings for the treatment works, further studies were made at the experimental plant in a larger tank to ascertain the effect of "detention period" on the clarification of crude sewage of various strengths. The tank used for this investigation had an inside width of 30 inches, a length of 100 feet. Experiments were conducted with sewage depths of 2, 4 and 5 feet.

The results of this study, summarized graphically in Figure 1, confirmed the conclusions previously reached in work with the smaller tank. These

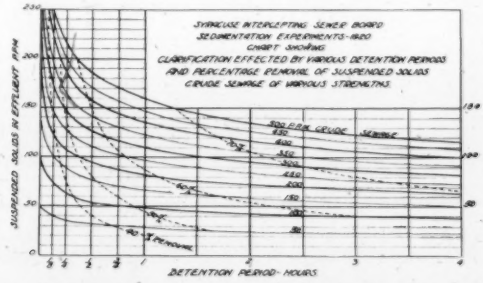

FIG. 1.—Percentage Removal of Suspended Solids.

conclusions were that a high removal of suspended solids could be obtained by plain sedimentation, with a comparatively short period of detention, if decomposition were prevented by frequent removal of the deposited sludge.

Sewage Treatment Works

The Sewage Treatment Works were completed and placed in continuous operation October 15, 1924, after a few weeks devoted to the training of an inexperienced personnel.

The sewage passes through the plant in the following order (refer to Figure 2):

1. **Venturi Flume.**—Designed to measure the total flow brought to the plant including the quantity of sewage bypassed.
2. **Overflow Chambers.**—Flows of 55.0 m. g. d. and less pass through the plant for treatment. The flow in excess of 55.0 m. g. d. is automatically bypassed to the lake shore through one section of the twin conduit.
3. **Coarse Rack.**—Inclined at an angle of 60 degrees from the horizontal. Bars spaced 2½ inches in the clear. Hand raked.
4. **Grit Chambers.**—Three compartments, each about 4 feet wide and 40 feet long.
5. **Fine Rack.**—Inclined at an angle of 60 degrees from the horizontal. Bars spaced ½ inch in the clear. Mechanically raked.

6. **Pumping Station.**—Main pumps and plant control; laboratory, work shop and locker rooms; houses fine racks and raking mechanism.

FIG. 2.—Syracuse Sewage Treatment Works.

7. **Venturi Meter.**—Equipped with indicating and recording mechanisms.

8. **Sedimentation Tanks.**—Four, each 71 feet square. Sewage depth 10½ feet at center. Tank bottom radial slope, rises 1 on 12. Dorr clarifier equipment.

9. **Outfall Conduit.**—Twin section. One conduit extends into the lake for about one-third of a mile and terminates about 25 feet below mean lake level. The other conduit conveys bypassed sewage and terminates at the lake shore.

10. **Sludge Pumping Stations.**—Sludge pumps and their controls.

11. **Sludge Force Main.**—Five-inch wrought iron pipe extending 12,000 ft. to Solvay Process Company waste beds.

Pumping Equipment and Control

The functioning of the overflow chamber and the velocity of sewage through the grit chamber are automatically controlled by the sewage pumps (Figure 3). The four main pumps, one of which is a spare unit, are the Morris 24-inch, centrifugal type, horizontal shaft, direct coupled to Westinghouse 75 H. P. slip-ring motors. Variable speed control is obtained through a float-actuated master controller (Figure 4), regulating pump delivery in accordance with the volume of inflowing sewage. This control automatically regulates the depth of flow and maintains a constant velocity of about one foot per second through the grit chamber.

FIG. 3.—Main Pumping Station—Interior View.

During flows exceeding a rate of 55 m. g. d., the maximum quantity treated, gates at the entrance of the grit chamber are also automatically float-controlled to maintain the level in the grit chamber to the optimum height for the 55 m. g. d. rate. Excess flow backs up, discharges over the weir of the overflow chamber, and is bypassed to the lake shore.[1]

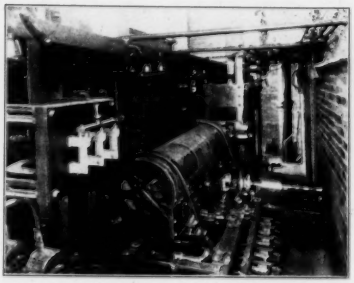

FIG. 4.—Rear of Control Board Showing Master Controller Drum.

[1] A more complete description of the plant and its control will be found in *Engineering News-Record*, **89**, 1121 (1922).

Operating Data

Operating data for the years 1925 to 1928, inclusive, are summarized in Table I.

TABLE I

SYRACUSE SEWAGE TREATMENT WORKS, OPERATING DATA, HIAWATHA STREET PLANT

Item		1925	1926	1927	1928
Plant in operation	Days	310.7	357.1	360.0	360.4
Total quantity treated	M. g.	5601	6957.31	7309.40	9692.31
Average daily quantity treated	M. g.	18.02	19.45	20.30	26.87
Maximum day	M. g.	47.84	44.51	48.11	48.80
Minimum day	M. g.	12.33	12.01	14.01	16.02
Total coarse screenings	C. f.	3739	6032	6872	8215
Total fine screenings	C. f.	5498	7212	8154	7318
Total coarse and fine screenings	C. f.	9237	13244	15026	15533
Coarse screenings per m. g.	C. f.	0.67	0.87	0.94	0.85
Fine screenings per m. g.	C. f.	0.98	1.04	1.11	0.75
Total screenings per m. g.	C. f.	1.65	1.91	2.05	1.60
Total coarse and fine screenings, day	C. f.	29.8	37.1	41.7	43.1
Total grit	C. f.	13960	14387	15366	19190
Grit per m. g. sewage	C. f.	2.49	2.07	2.10	1.98
Grit per day	C. f.	45.0	40.3	42.7	53.2
Total scum removed tanks	C. f.	234	697	730	894
Scum per m. g. sewage	C. f.	0.042	0.100	0.100	0.092
Scum per day	C. f.	0.753	1.95	2.03	2.480
Total sludge pumped from tanks	M. g.	68.456	39.61	41.77	67.24
Sludge per m. g. sewage	Gal.	12200	5700	5715	6940
Sludge per day	M. g.	0.220	0.111	0.116	0.186

Volume Sewage Treated.—It will be observed that the quantity of sewage pumped and treated has increased each year. The large increase in the daily average for 1928 is due partly to the greater care exercised in the supervision of the intercepting sewer system, thus preventing the overflow of sewage into the water courses, and partly to the admission of drainage incidental to the construction of public work. Care of the intercepting system in former years was not a duty of the Bureau of Sewage Disposal.

The water consumption in the contributing area has been estimated for the year 1928 as 133 g. c. d. as compared with the 147 g. c. d. of sewage treated.

Character of Sewage.—The sewage of Syracuse on reaching the treatment works is comparatively fresh, uncomminuted and of average strength; the sewage contains comparatively little industrial waste; total suspended solids average about 200 parts per million.

Clarification Effected.—The monthly averages of the daily analyses of the crude sewage and plant effluent for the years 1927 and 1928 are given in Columns 1 and 2 of Table II. Column 3 shows the average percentages of removal during each month, Column 4 shows the average

anticipated percentage of removal, based on the experimental results of the small tank (Figure 1) and Column 5 shows as a percentage how nearly the actual removal agrees with the anticipated removal. The above data together with other information regarding the volume of sewage treated and the detention periods are shown graphically in Figure 5.

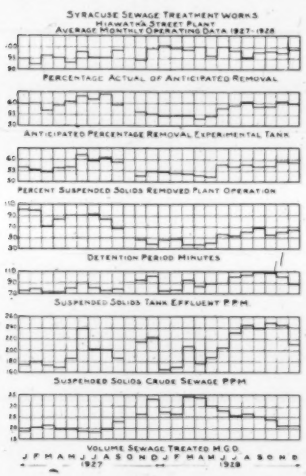
SYRACUSE SEWAGE TREATMENT WORKS
HIAWATHA STREET PLANT
AVERAGE MONTHLY OPERATING DATA 1927-1928
PERCENTAGE ACTUAL OF ANTICIPATED REMOVAL
ANTICIPATED PERCENTAGE REMOVAL EXPERIMENTAL TANK
PERCENT SUSPENDED SOLIDS REMOVED PLANT OPERATION
DETENTION PERIOD MINUTES
SUSPENDED SOLIDS TANK EFFLUENT P.P.M.
SUSPENDED SOLIDS CRUDE SEWAGE P.P.M.
VOLUME SEWAGE TREATED M.G.D.
J F M A M J J A S O N D J F M A M J J A S O N D
1927
1928

FIG. 5.—Operating Data, 1927-28.

During 1927 four tanks were in service. During 1928 three tanks only were operated to ascertain the effect of shorter detention periods. During this two-year period it will be observed that the actual removal of suspended solids fluctuated between 92.3 and 100.6 per cent of the anticipated removal, a comparatively narrow range. The average for 1927 with four tanks in service was 95.7 per cent and for 1928 with three tanks and shorter detention periods was 97.9 per cent. This close agreement is quite remarkable considering the great difference in capacity and form of the small experimental tank and those constructed at the treatment works.

TABLE II

MONTHLY AVERAGE OF DAILY ANALYSES AND REMOVALS TOTAL SUSPENDED SOLIDS 1927 AND 1928

1927	Crude Sewage P. P. M. 1	Tank Effluent P. P. M. 2	Per Cent Removal Actual 3	Per Cent Removal Antic. 4	Per Cent Act. of Antic. 5
Jan.	174	76	56.7	59.8	94.7
Feb.	177	79	55.4	60.0	92.3
Mar.	172	72	54.5	56.7	96.2
Apr.	168	73	56.2	59.2	95.0
May	184	80	56.6	60.8	93.1
June	238	89	61.8	63.2	97.8
July	202	81	59.1	61.8	95.5
Aug.	199	76	60.8	63.9	95.2
Sept.	184	78	58.4	59.3	98.4
Oct.	..	No samples taken	..	..	..
Nov.	214	94	52.7	56.1	94.1
Dec.	222	101	54.6	55.2	99.0
Ave.	193	82	57.0	59.6	95.7

TABLE II—(*Continued*)

1928					
Jan.	164	75	54.3	54.0	100.6
Feb.	168	77	53.8	54.3	99.2
Mar.	206	94	53.6	54.3	98.5
Apr.	175	83	52.8	52.8	100.0
May	186	88	52.0	54.2	95.9
June	205	89	57.4	57.6	99.7
July	231	100	56.6	58.7	98.2
Aug.	243	103	57.5	60.4	95.2
Sept.	238	107	56.5	57.9	97.5
Oct.	248	106	56.8	58.2	97.8
Nov.	245	101	58.7	60.5	97.0
Dec.	210	87	58.6	59.4	98.5
Ave.	210	93	55.7	56.8	97.9

Screenings.—The coarse rack preceding the grit chamber, with bars spaced $2^1/_2$ inches in the clear, is raked by hand about once every hour during normal conditions. Storm flows necessitate more frequent cleaning.

The character, as well as the quantity of material collected, varies somewhat with the flow and the season of the year. The coarse screenings consist largely of paper, rags, a small amount of fecal matter, brush and blocks of wood. Leaves during the fall months add greatly to the bulk of the stranded matter and the labor of cleaning.

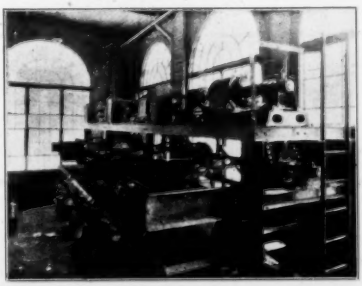

FIG. 6.—Screen Raking Mechanism Showing Drive and Hoppers.

The fine racks are constructed in three separate units, one for each grit chamber compartment, and are housed within the pumping station. The bars are spaced $^1/_2$ inch in the clear and are mechanically cleaned every 30 seconds by continuously moving rakes. These rakes elevate the screenings to the ground floor of the station where they are deposited in perforated metal containers (Figure 6).

The function of these fine racks is to remove only those objects which, on account of their size, might interfere with the further stages of treatment and disposal. They were designed and installed particularly for the prevention of stoppages in the 5-inch sludge force main.

The screenings from the fine racks are quite different in character than

those from the coarser rack. The fine screenings contain more putrescible matter, and much less paper and rags.

The coarse screenings, after draining on the platform, have a moisture content of about 83.5 per cent; the fine screenings, which drain on the rake fingers while being elevated and also in the containers, reach a moisture content of about 64.5 per cent. Disposal of both the fine and coarse screenings on low ground in the vicinity of the plant, by covering with material from the grit chamber, has been satisfactory.

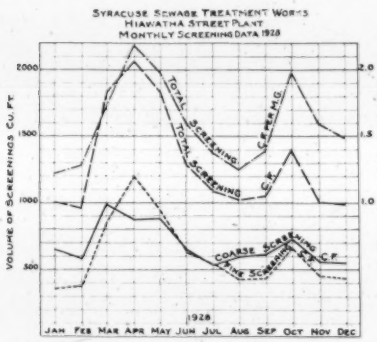

FIG. 7.—Average Monthly Volume of Screenings in 1928.

The monthly variations in the volume of the coarse and fine screenings for 1928 are summarized in Table III and may be more clearly visualized by referring to Figure 7.

TABLE III

VOLUME OF SCREENINGS 1928

	Sewage Screened, M. G.	Coarse Screenings, C. F.	Fine Screenings, C. F.	Total Screenings, C. F.	Total C. F. Screenings, per M. G.
Jan.	829.52	652	358	1010	1.22
Feb.	754.80	583	381	964	1.28
Mar.	1070.05	990	849	1839	1.72
Apr.	944.69	867	1196	2063	2.18
May	928.91	883	953	1836	1.98
June	802.58	651	634	1285	1.60
July	785.08	536	545	1081	1.38
Aug.	817.94	599	422	1021	1.25
Sept.	755.63	614	436	1050	1.39
Oct.	705.41	733	662	1395	1.98
Nov.	636.87	558	451	1009	1.59
Dec.	660.83	549	431	980	1.48
Total		8215	7318	15533	
Ave.	26.77[1]	685[2]	610[2]	1295[2]	1.60

[1] Per day.
[2] Per month.

Grit.—The grit chamber, which is about 40 feet in length, is separated into 3 compartments by two low dividing walls. The number of com-

partments in service depends upon the rate of sewage flow, one compartment for 18.3 m. g. d. or less, two compartments for 18.3 to 36.7 m. g. d., and three compartments for flows of from 36.7 to 55.0 m. g. d. The depth of flow, as previously stated, is automatically varied by pump control to maintain a constant velocity through the chamber of approximately one foot per second. The detention period is accordingly about 40 seconds.

The compartments are cleaned without unwatering by a clam shell bucket and traveling hoist, operated from an overhead monorail track system. The bucket and hoist are controlled by an attendant in a cab which is an integral part of the traveling mechanism (Figure 8).

The chamber is ordinarily cleaned once each week. Daily removal of grit is usually necessary during times of melting snow and following heavy precipitation. Although the total quantity of grit removed is increasing annually due to extensions of the sewer system, it will be observed that the quantity per million gallons treated is not increasing proportionally. This may be accounted for by the extensive paving program of the past few years.

FIG. 8.—Grit Removal Equipment.

The grit, consisting largely of sand and cinders, is used for covering the screenings and for surfacing roadways and walks about the plant. It is inoffensive and at no time have odors been noticeable in the vicinity of the deposits. Analyses show the organic content usually varies between 5 and 10 per cent.

Scum.—The floating matter, which collects on the surface of the sewage in the settling tanks, is composed largely of waste oil and grease from public and private garages, particles of soap, animal and vegetable matter, matches, and organic débris. It is particularly offensive and troublesome.

Referring to Table I, it will be noted that the quantity of scum is increasing each year very rapidly. The average removal per day in 1928 was more than three times that of 1925.

Removal from the tanks is accomplished by skimming, after working the scum to one corner of each tank by a jointed float. During the first year of plant operation the scum was buried with the screenings, but this was not satisfactory. It was found that this material burns readily when spread in thin layers to allow the surplus water to drain and evaporate. This method of destruction is now used successfully.

Sludge.—The volumes of sludge pumped for the several years (Table I) are not comparable on account of different operating schedules. The

sludge deposited in the sedimentation tanks is concentrated by the Dorr Clarifier (Figure 9) and then pumped to the place of disposal.

The plant, when started in operation, was the first to attempt the pumping of sewage sludge through so small a pipe for such a distance. Owing to the fact that no information was available regarding the velocity necessary to prevent segregation and frequent stoppages in the force main, the schedule of operation at first called for continuous pumping from all four tanks. This maintained a large flow of highly diluted sludge. Operating experience has proven that a smaller quantity of more concentrated sludge may be pumped at lower velocities without difficulty. At present the usual schedule calls for pumping from each tank in rotation for about 3 hours or twice per 24 hours. When the load on the plant is above normal, it is necessary to pump more frequently, and occasionally from all tanks.

FIG. 9.—One of the Dorr Clarifiers.

The variation in pumping head on the sludge force main is illustrated in Figure 10, reproduced from the chart of the recording pressure gage for the week beginning Sunday, July 10, 1927. The static head at this time was about 30 feet. The friction head varies both with the quantity pumped and the consistency or moisture content of the sludge. Other information has been added to the chart to show the simultaneous variations in sewage flow, and the number of sludge pumps in service.

This particular chart was chosen since it illustrates the effect of heavy precipitation; two storms caused peak flows, one of 50 m. g. d. shortly after 6 p. m. on Monday the 11th, and another of 52 m. g. d. about 5 p. m. on Friday the 15th. Information is not available as to the consistency of the sludge during this time.

TABLE IV

PER CENT MOISTURE SEWAGE SLUDGE PUMPED

	END SAMPLING PERIOD—MINUTES AFTER STARTING PUMP									
1929	5	10	15	20	25	30	45	60	90	120
Jan. 31	99.3	99.6	99.5	99.8	99.7	99.8	99.5	99.5	99.4	99.4
Feb. 2	98.8	99.3	98.6	99.2	99.0	97.8	98.5	98.5	98.7	98.8

Table IV summarizes the results of two series of analyses of the moisture content of sludge during pumping from Tank 4. Samples were collected each minute and composites made for analysis of each 5-minute period

throughout the first half-hour. Composites for the later period were made from samples collected at the stated time. No pumping had been done from the tank during the eight hours preceding these tests.

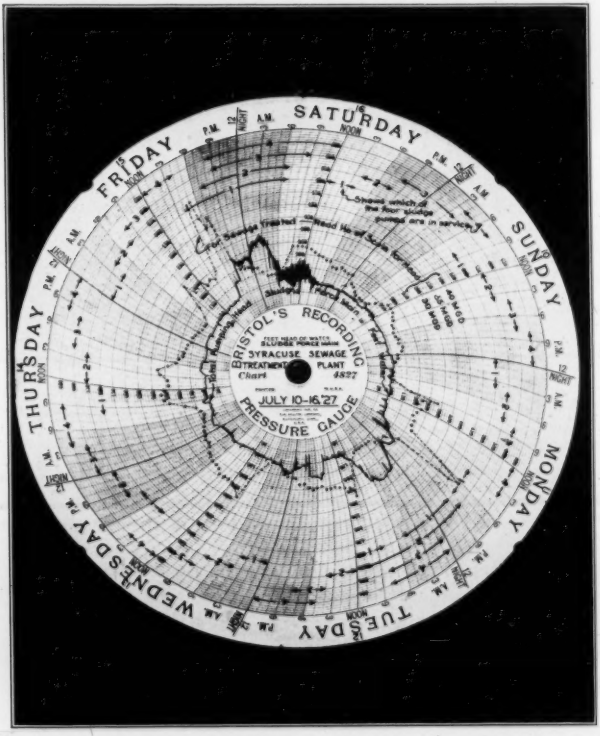

FIG. 10.—Record of Sludge Pumping, July 10–16, 1927.

Construction Costs

The construction costs of the sewage treatment and disposal works are given in the following summary. These costs are in part approximate as several of the structures were built under lump sum contracts that segregated the work under different groupings than listed in Table V.

TABLE V

CONSTRUCTION COSTS. SEWAGE TREATMENT AND DISPOSAL WORKS

Pumping station and grit chambers	$ 74,645	
Machinery and equipment	76,100	
Mechanical screening equipment	18,200	$168,945
Sedimentation tanks	115,032	
Sludge removal equipment	37,987	153,019
Sludge pumping stations	7,822	
Sludge pumping equipment	20,436	
Sludge force main	64,600	92,858
Transformer substation	3,391	
Feeder cables and conduits	1,800	
Exterior lighting	4,919	10,110
Total Treatment Works and Pumping Station		$424,932
Outfall conduit to lake shore	38,953	
Subaqueous conduit to deep water	66,490	
Total Outfall Works		105,443
Venturi flume	4,200	
Overflow chamber	5,000	
Shore relief conduit	38,952	
Total Storm Overflow Works		48,152
Grand Total Sewage Disposal		$578,527

The plant was designed for a population of 200,000. The per capita construction cost on this basis is, therefore, $2.90. The factor of safety used in designing the sedimentation tanks to ensure an effluent averaging not more than 100 p. p. m. has proven more than ample.

Operating Costs

Expenditures from the annual budget appropriation of the Bureau of Sewage Disposal, Department of Public Works, charged to operation and maintenance of this plant are shown in Table VI. Actual costs are somewhat less because of the inclusion of certain items which in reality should be charged elsewhere. For example, the entire salaries of the Superintendent and the Analyst of the Bureau are included under "Payroll;" half of the Superintendent's time and one-third of the Analyst's is chargeable to other duties. "Additions to Plant" should be charged to construction or installation of equipment. The item of $4380.44 in 1928 includes a static condenser costing $3600 which will be installed in 1929 for the purpose of improving the power factor and reducing the cost of power. The

Table VI

Operation Costs. Sewage Treatment (Including Pumping)
Hiawatha Street Plant

	1925 Fiscal Year*	1926 Calendar Year	1927 Calendar Year	1928 Calendar Year
Payroll employees	$29,067.83	$30,735.24	$32,351.00	$33,180.33
Electric power and light	9,994.60	12,170.95	11,723.40	12,578.95
Heat, coal and coke	843.99	627.88	547.73	490.88
Additions to plant	435.29	1,426.29	718.54	4,380.44
Equipment and tools	459.36	222.31	88.38	.....
Miscellaneous supplies	597.88	2,290.48	1,508.11	2,227.00
Repairs and replacement	876.06	1,817.94	3,431.74	2,682.14
Oil, grease, gasoline, waste	291.40	352.32	312.55	436.49
Soap, towels, toilet paper	60.16	63.05	187.23	160.46
Telephone	153.40	108.20	108.32	128.91
	$42,779.97	$49,814.66	$50,987.00	$56,265.60

* Dec. 1, 1924, to Nov. 30, 1925.

same explanation applies to "Equipment and Tools." Duplicate equipment and spare parts have been purchased and placed in stock for replacement of units and parts most likely to need repair. These purchases include motors, speed reducers, wash water pumps, plungers and valves for sludge pumps, varied electrical equipment and many other such items. These spare parts will eventually be used for repair and replacement but since they have not all been used, only a portion of the amounts included are strictly chargeable to operation or maintenance for these years.

Payroll Employees include one Superintendent, $3600; one Chief Operator, $2400; three Operators, $2100; one Chief Attendant, $1980; four Attendants, $1800; one Analyst, $1800; one Assistant Attendant, $1500; and eight Laborers at $4.00 per day.

Electric Power and Light.—This service is purchased from the Syracuse Lighting Company at the standard wholesale power (two-charge) rate; a demand charge plus an energy charge. The demand charge for billing is taken as the highest average load in kw. occurring during any 15 consecutive minutes of the month corrected by a multiplier depending on the power factor. Power factors less than 70 per cent result in a penalty. The charge for the first 100 kw. of demand is $192.50; additional demand is computed at $1.25 per kw. The energy charge for the first 10,000 kw. hr. (in any month) is $142.50; additional kw. hr. are charged at 0.85 cent per kw. hr. A 5 per cent deduction in the total kw. hr. is allowed for metering on the primary side of the transformer.

Heat, Coal, Coke.—This item covers the cost of fuel for heating the pumping station, including the screen room which houses the cleaning mechanism of the fine racks. Anthracite coal was burned in 1925 and during the

spring of 1926; since that time coke has been used exclusively, at an appreciably lower cost.

TABLE VII

UNIT OPERATING COSTS. BASED ON BUDGET EXPENDITURES

	1925	1926	1927	1928
Cost of disposal, per m. g. d.	$7.63	$7.16	$6.98	$5.82
Cost of disposal, per capita	..	..	..	0.31
Cost of electric power, per m. g. d.	1.78	1.75	1.61	1.30
Cost of labor, per m. g. d.	5.18	4.42	4.42	3.42

It will be noted that the cost of power per m. g. pumped has been reduced from $1.78 in 1925 to $1.30 in 1928, or about 27 per cent. This reduction is due partly to more efficient operation and partly to the effect on unit power price of a better plant load. The static condenser now being installed (March, 1929) is expected to eliminate the demand penalty and maintain a power factor of unity. This will further reduce the cost of pumping.

Summary

The operation of the plant has fully justified all expectations. The removal of suspended solids has exceeded the requirements originally set for satisfactory performance and is in close agreement with the early, small-scale experiments. Fish life in Lake Onondaga, formerly absent, is reported to be increasing each year.

Comparatively little trouble has been experienced in plant operation. Only three stoppages have occurred in the sludge force main, none since March 26, 1926, and these were removed in a few hours and without interruption to the other units of the plant.

The short detention of the sewage as it passes through the several stages of treatment, the prompt removal of sludge without exposure to sight and the method of sludge disposal employed effectively prevent the creation of any offensive odor and have occasioned much favorable comment.

Handling Activated Sludge on Covered Beds

BY WELLINGTON DONALDSON[1] AND A. LAWRIE KURTZ[1]

The disposal of the voluminous sludge produced by the activated sludge process has been a serious obstacle to the use of this attractive method of sewage treatment for small communities. With few exceptions efforts to dispose of the sludge without digestion or mechanical dewatering equipment have proven unsuccessful. This paper describes the experience gained in solving the sludge problem of a small plant at Tenafly, New Jersey.

The Borough of Tenafly is a residential suburb of New York City having a population of about five thousand. It is situated on the west slope of the Palisades in the Hackensack River Valley sixteen miles north of Jersey City. It is reached by the Piedmont Branch of the Erie Railroad from Jersey City, by two bus lines from New York City or by street car from the Fort Lee Ferry opposite 125th St.

During 1927–28 a separate system of sewers was installed together with a disposal plant designed for an unusually high degree of treatment. Previous to this the liquid wastes of the community were cared for entirely by individual cesspools.

The plant, which went into operation on Feb. 24, 1928, comprises preliminary treatment by 2-in. bar screen and Link-Belt fine screen. The main treatment is by the activated sludge process followed by sand beds and chlorination. Screenings are stored and reduced in compost cells. The excess activated sludge is dried on glass-covered sand beds from which it is removed and utilized for filling low areas around the plant, and to some extent for fertilizer.

The plant is designed for a population of 7500 with flow of 100 gallons per capita. The present flow is 270,000 g. p. d. although it has reached a peak of nearly 750,000 g. p. d. for short periods due to infiltration and surface water, which condition has since been corrected.

Since the plant was put in operation, connections have steadily been changed from the cesspools to the sewer system and now number 906, serving about 4000 people.

The sewage being treated is entirely domestic, from a separate system of sewers. It contains 3 cc. of settling solids per liter before screening and 150 p. p. m. of suspended solids after screening. An average of 12 cu. ft. of screenings are produced daily.

The operation of this plant has been exceptionally satisfactory since the first day it was put in service. The final effluent has been uniformly clear, free from odor and practically sterile. The biological reduction of screen-

[1] *Fuller & McClintock, Consulting Engineers, New York City.*

ings in the compost cells is progressing without nuisance and the handling of the excess activated sludge is likewise unattended by nuisance.

The excess activated sludge is drawn by gravity onto the sludge beds from the return sludge mains. These beds are located in two glass-covered houses as shown in Figure 1, each house having four beds 24 ft. × 39 ft. in plan, giving an area of one square foot per capita of designed capacity. During the early stages of operation when it was desired to draw sludge one of the return lines was shut off and the sludge was allowed to accumulate in one of the two clarifiers for 4 to 6 hours, then discharged as a batch upon a bed. The dose as measured by displacement in the clarifier amounted to 2000 to 3000 gallons or from 2.1 to 3.2 gallons per square foot of sand surface. This is equivalent to from $3\frac{1}{2}$" to 5" depth on the bed.

FIG. 1.—General View of Tenafly Sewage Works.

In the course of six or seven days the sludge layer dried down to a thickness of $\frac{1}{8}$" when it checked and curled up and could be easily removed after raking into a pile. The water content of the wet sludge was not at that time determined but the dried cake contained from 70% to 80% dry solids. Figure 2 shows a typical bed ready to be cleared. During this period the return sludge flow was held at about 30% of the raw sewage flow. Excess sludge was drawn when necessary to restrict the solids in the aeration tank effluent to 30%, as shown by $\frac{1}{2}$ hour's settling test in 100-cc. cylinders.

With the beginning of the 1928 summer season, the strength of sewage increased, due to added connections to the system, and it became necessary to draw more sludge. The increased dosing, together with the high tem-

peratures within the glass houses, resulted in a tendency of the sludge to turn black and produce odors on the bed. The drying area was inadequate under these conditions, and therefore some sludge was drawn to trenches in the sandy fill around the plant structures. The use of trenches as a temporary expedient facilitated the fertilization of the sandy areas for grass growing, and thus served a double purpose. Trench disposal could not be continued indefinitely and a serious study was made of ways and means to improve the condition of the sludge to permit heavier bed dosings with a resulting cake which could be readily removed without producing odors.

It was found that the retention of sludge in the clarifier preliminary to dosing caused a deterioration in its condition, also that the settling tests

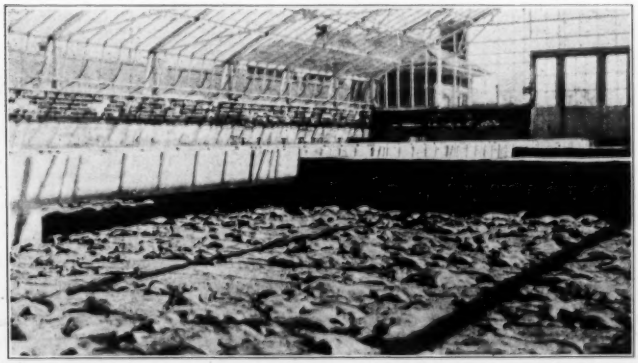

FIG. 2.—Appearance of Dried Sludge on Beds During First Stages of Operation (70–80% Dry Solids).

alone were unreliable as a measure of the concentration of solids in the aeration tank. The dry solids in the aeration tank effluent at that time were 0.17% by weight and the settling test showed 68% by volume, whereas at present the aeration tank effluent carries 0.39% dry solids by weight but shows by the settling test 23% by volume. As a result of these findings some changes were made in operating methods.

Temporarily the rate of return sludge was increased to about 40%, the aeration period was doubled by putting the second aeration tank in operation and no sludge was drawn for twelve days. Instead of concentrating sludge in a clarifier before dosing a bed it was drawn at a slow rate from the return sludge lines. Screed board guides were placed in the beds, making it possible to trim them to a true surface having a slope of 0.63 ft. per 100 ft. in all directions from the feed valve.

As a result of the changes in operating methods, the dry solids in the aeration tank increased to 0.57% by weight showing 50% by volume on settling. The sludge readily drained on beds to a removable condition in 4 to 5 days without odor and retained its light color.

As the winter of 1928–29 approached it was expected that a natural decline in sludge condition would occur and that the glass houses would require heating. Fortunately these expectations did not materialize.

Throughout the past winter, one bed has been dosed daily with about 1800 gallons of sludge having an average of 2.5% dry solids. A cake from $^3/_4$ in. to 1 in. thick containing from 20% to 25% dry solids was produced in 4 to 5 days. On a few occasions sludge dosed on the beds in the afternoon was readily removed the following morning. The sludge cake has

FIG. 3.—Bed Being Dosed with Wet Sludge.

shown no tendency to freeze on the beds. During the coldest weather, with a minimum temperature of 10° F. in the houses, only the top $^1/_4$ in. has shown ice crystals.

The procedure now followed is to dose a bed by cracking the valve connected with the return sludge line, allowing the sludge to flow gradually over the bed as shown in Figure 3. Most of the water quickly separates from the solids and runs ahead into the sand before it is sealed by the solids. This is continued until the entire bed is covered, precaution being taken not to allow too heavy a blanket to be formed near the feed point. The dosing operation takes about 30 minutes and in about 2 hours all free water has disappeared from the surface. For removal, the sludge layer is marked into squares the size of the lifting fork as shown in Figure 4. The

fork used has tines about 1 in. apart which are slipped under the section of cake and lifted. A slight bounce of the load releases most of the sand ad-

FIG. 4.—Removal of Sludge Cake (20–30% Dry Solids).

FIG. 5.—Sludge Dump.

hering to the bottom and the cake is then thrown into a wheelbarrow and conveyed to a movable elevated runway where it is dumped in a pile as shown in Figure 5, and later covered with earth.

From one to two wheelbarrows of sand are required in the cleared bed to make up for that removed with the sludge and the bed is then trimmed to surface for the next dose. The dosing of the bed is done by the operator in charge and the cake is removed and the bed trimmed by a laborer. A bed can easily be cleaned and resurfaced in half a day.

With a view of further conditioning the sludge to permit higher doses a 5000-gallon steel tank has recently been erected. It is proposed to draw the excess sludge slowly into the tank and keep it in condition with air supplied by a system of perforated pipes until ready for discharge on the beds. This tank will permit accurate measurement of sludge quantities and will allow the mixing of a conditioning chemical if desired. To date no conditioning chemical has been used except in an experimental way.

Trials and Tribulations of a Sewage Works Operator[1]

BY A. W. WYMAN[2]

The subject of this paper takes us back to many unpleasant experiences, and except for the many benefits others as well as we ourselves derive from them, we wouldn't care for any post mortems. Trials and tribulations are caused by failures, some impossible to forecast and others by poor judgment or lack of experience.

At the time Pasadena's plant was started, in January, 1924, the activated sludge process in this country was not very far advanced, so naturally many errors were made, some pretty expensive and others merely operators' problems.

Initial Operating Difficulties

The first serious one, and one which is so often made even by capable engineers, was lack of capacity. This started a prejudice against the plant which has not been entirely overcome as regards our near neighbors. Many figure that if the average daily flow is provided for, enough energy can be stored during low flow to take care of the peaks. This in my experience is entirely wrong, especially when our peak flow (nearly double our average flow) lasts longer than the four-hour detention period which we have found necessary for good results. This lack of capacity included aeration units, clarifiers, sludge return pumps and sludge filters. It had been decided to discharge the effluent into a wash just below the plant, but at the last minute an order from the State made this impossible. The reason for this was that, during the two weeks' period after starting a plant, the effluent is very little better than raw sewage, and the stability of effluent at all times must come up to state and county requirements. Besides, the wash, for the most part, ran through private property.

Here was the operators' problem: how to return to the farm property all the effluent, with a pump capacity of about half that amount. The only alternative was to control the raw sewage flow into the plant and bypass the surplus into lagoons or basins. Many thousands of dollars were spent in building basins for this purpose, and it was in the lagooning that the plant got its bad name. New aeration and clarifier units were rushed to completion, and finally an effluent line from the plant to the Rio Honda was built, which removed the necessity of lagooning the raw sewage.

Sludge Disposal

In the meantime the sludge problem was causing more concern than had the raw sewage. High pressure salesmanship, and a wonderful article,

[1] *Reprinted from California Sewage Works Journal, Vol. 1, No. 1, pp. 102–111. 1929.*

[2] *Superintendent, Pasadena Sewage Treatment Plant.*

appearing in a well-known engineering magazine, contributed by the salesman himself, had sold the city a filtering machine used in the paper industry. This machine was housed in a very fine building arranged for its accommodation only, and which later required much serious study to rearrange for filters that are filters.

Going back to the paper machine, a company engineer was supplied with the equipment to prove their guarantee, that of filtering all excess sludge produced by the plant using SO_2 gas as a coagulant. After one or two months' experimenting, this machine was declared worthless, and only by starting suit did Pasadena receive the money paid for it. While all this was going on, sludge was being pumped to lagoons, used for irrigating the orange orchards, and in fact everything which could be thought of to dispose of it. The trials and tribulations during this period are still fresh in my mind. A real nuisance and probably a menace to public health existed. Flies and mosquitos were breeding by the thousands, and irate neighbors and State Board of Health and County officials were insisting upon quick action, our neighbors even going so far as to threaten to blow up the plant. City officials were back of every move to improve the situation, in fact have always been more than liberal in meeting the requirements of the plant. Trenching was finally adopted, and hundreds of ditches were necessary to hold the half liquid sludge which had been accumulating between the failure of the paper machine and the installation of two large vacuum filters. These filters needed many months to bring them to the efficient stage which they now hold. One instance about these first filters I well remember. Cotton cloths costing about $50 each were lasting only 30 or 40 days. These cotton cloths filtered 4,500,000 gallons in thirty days of continuous service. We are now using woolen cloths at $75 each, which last six months and filter 30,000,000 gallons each.

Air Distribution

Another serious and costly error was the manner in which filtrous plates were set. Asphaltum was used for cementing the plates, and many leaks were discovered when the plates were covered with a few inches of water to test them out. Once the plates were wet it was next to impossible to make asphaltum stick and stop the leaks. These leaks increased in number until nearly all the air was coming up around the plates, and uniform air distribution, which is very important, was impossible. This left nothing to do but remove the plates, one tank at a time, and chip off the concrete edges of the holders where the tar still prevented a bond for the new setting in concrete. Each plate was washed in carbon bisulphide, coal oil, and water before it could be used again, and instead of having new plates of uniform porosity, they were now only about 75 per cent efficient. This was some job in itself, there being about 3000 plates. These plates

are still in service, but will be replaced with new plates from time to time. It is hoped this may show quite a reduction of the amount of air now used.

The blowers also caused their share of trouble. Check valves of the swing type were responsible for a general scramble for the power house to close a positive gate valve, and save some blower from tearing itself to pieces in reverse gear on account of air rushing back through a stuck check. These have been replaced by cushion plunger type checks, needing almost no attention. A gravity oiling system relieves the operator from the tiresome and almost continuous necessity of hand oiling.

Screens and Settling Tanks

The screen house gives very little trouble since the bucket conveyors have been changed from a two-chain drive to a single chain. The fine screens are very efficient, but I am sorry I cannot say the same about the clarifiers, that is, the type which was furnished the Pasadena plant. These were of the extension arm type which operated from weights and wire cables. The wire cables were replaced many times, until cable chain and chain sheaves were finally furnished. These worked. The extension arms have been discarded and all clarifier tanks (now five in number) have been changed from square to round bottoms, making it possible to try out spiral equipment, which has been very satisfactory. Nearly all these troubles are ancient history, licked and almost forgotten, but there are still one or two quite recent ones.

Drying of Sludge

Burying sludge was using up all surplus waste land, and, besides being a very expensive disposal, began to cut into valuable farm land. Sun drying was out of the question in the present location, so a sludge dryer was installed, and tested out in February, 1927. The dryer was a direct indirect type, 70 in. diam. and 42 ft. long, with a Dutch oven using fuel oil under 70 lb. pressure. An exhaust fan of 8000 c. f. m. gave the forced draught necessary and carried the gases and steam away through a coke filter. The guarantee of this dryer was that it would dry 500 lb. per hour of feed sludge, containing 83 per cent moisture, and that no odors would result. But 300 lb. was the very best the dryer would turn out, and as to odors, there were plenty. The coke filter, heavy water sprays, and finally chlorine as high as 150 lb. per day, gave no relief. In addition to these, we tried blowing the exhaust gases up the incoming sewer line, but they escaped from manholes and the odor was still as bad. Then it was turned down the effluent line, with no outlet until it reached the Rio Honda, four miles away. This gave promise of some relief, but was soon reported to county and health authorities as causing death and destruction to people living half a mile away from the discharge. An ozone

generator of 12 grams per minute capacity had been given credit for a slight improvement, so another ozone machine of double the capacity was purchased on a guarantee that all odors would be eliminated or no money. Both machines are still in storage, and the second has not been paid for. A compromise was made on the dryer, on the basis that it should deliver three tons per 24 hours instead of six, as guaranteed. This left a real problem for the operator. Dryer capacity was less than half that required by the plant. Many changes were made in the dryer. It was lengthened to 60 ft., a new circular fire box was built, also a screen and return conveyor for oversize material. This stepped up the output to 4½ tons per day, still not enough. Experiments with a filter aid almost immediately brought the results we desired. Filter capacity was increased nearly 50 per cent, and the moisture of the sludge cake was reduced more than 5 per cent. The effect on the dryer was very pronounced, jumping the capacity to 8 or 10 tons daily. This was very gratifying as far as the dryer was concerned, but the odors were still causing many protests, and finally an order came to close down the dryer until some means could be worked out to eliminate the odors.

Summing up everything that had been tried without success—condensers, water-washers, sprays, deodorizers, chlorine and ozone—we next tried superheating the steam and passing it through a separate fire-box. This fire-box is about 6 ft. wide and 20 ft. long, having an outside shell through which the gases and steam pass before going into the combustion chamber itself. There are over-and-under baffles which insure contact for all gases, and a 20-ft. stack discharges them into the outside atmosphere. This arrangement seems to be exactly what was needed for the elimination of these odors, and I believe is the solution of the most persistent of all our problems.

This paper possibly has left an impression that everything must have gone wrong at the Pasadena plant, but such is not the case, for many installations have worked to perfection from the start. Looking back over the last five years, the satisfaction of permanently solving these many problems makes the trials and tribulations of the sewage plant operator not so serious, after all.

Discussion

The paper elicited much applause, especially for the frank way in which Mr. Wyman told of his periods of discouragement and the admirable persistence with which he overcame each obstacle.

Mr. Warren, along with many others, was much interested in the reference to the revenue from sludge drying and the net costs of operation. Mr. Wyman explained that the accounting system is a little unfortunate, inasmuch as construction has been going on every since the plant began,

and in the auditing department it has been easy for operating and capital expense to become interchanged. It was obviously unfair for anyone to think that the revenue from the sludge carried the whole plant operation but he was sure it would carry all the expense of drying; but it was not clear whether it would cover the expense of filtration of the sludge. At the request of the editorial committee, Mr. Goudey has gone into the cost records and gives the following figures:

General Data

Present population sewered	114,000
Present average sewage flow	7 m. g. d.
Ultimate population	157,000
Ultimate average sewage flow	11 m. g. d.
Aeration tanks, capacity 2.25 m. g.; re-aeration tanks, 0.37 m. g.; final clarifiers, 1.12 m. g.	

The costs to be presented are intended for their usefulness elsewhere. Hence certain development expense incidental to a pioneer enterprise and not affecting the present basis of operation is omitted. However, that the full cost data as carried in the city comptroller's books may be made known, all items in the comptroller's report not used here are itemized at the close of this discussion.

Capital Expense

Original investment, for construction and design, 1923	$447,249.52
Additions and remodeling, 1924, to Sept. 30, 1928	279,926.05
Total capital cost to Sept. 30, 1928	$727,175.57

Hence cost per m. g. d. capacity, present, $104,000; ultimate, $66,000; and cost per capita, present, $6.37; ultimate, $4.63.

Operation Expense

These figures are based on the operating costs July 1, 1928, to September 30, 1928, inclusive, during which time the plant has been operating under normal conditions reproducible elsewhere. They allow for bills outstanding September 30, 1928. No allowance is made for anticipated economies in use of chemicals based on experimental work in progress. During this period the governing operating data were as follows:

PRINCIPAL OPERATING DATA, JULY 1, 1928, TO SEPT. 30, 1928

Total sewage treated in period	615,700,000 gal.
or 6.7 m. g. d.	
Air used	1,292,340,000 cu. ft.
or 2.1 cu. ft. per gal.	
Electrical power all purposes	1,214,800 kw. hr.

Liquid sludge filtered	23,973,000 gal.
or 39,000 gal. per m. g. of sewage flow.	
Filter cake produced (80% water)	3223 tons
Water evaporated	2578.4 tons
Dried sludge produced	644.6 tons
or 1.05 tons per m. g. Note—On a year's basis, with average sewage flow 7.0 m. g. d., sludge produced would average 1.2 tons per m. g. During the spring, sludge production is highest and in summer lowest	
Alum used, 226,500 lb. or	113.2 tons
Celite used, 265,000 lb. or	132.5 tons
Chlorine (for sewage disinfection)	13,524 lb.
Gas for drying sludge	118,000 ± cu. ft.
Gas for burning drier gases	82,000 ± cu. ft.

OPERATION COSTS (PER 1,000,000 GALLONS)

		July 1, 1928, to Sept. 30, 1928 6.7 M. G. D.	Present Flow Ave. 7.0 M. G. D.	Plant Capacity 11 M. G. D.
			Est.	Est.
(A)	Screening, aeration, clarification and chlorination:			
	Labor, 3 men at $175 per mo.; 1 at $6.75 per day; 1 at $5.00 per day; 1 at $4.00 per day	$ 4.39	$ 4.11	$ 2.68
	Power ave. 0.88¢ per kw. hr. (pres.)	14.60	14.60	14.60
	Chlorine 22 lb. per m. g. at 6¢ lb.	1.32	1.32	1.32
	Miscellaneous oil and grease	0.08	0.08	0.08
	Maintenance and renewals	0.57	0.57	0.57
	Portion of general expense	2.01	1.92	1.23
	Sub-total, aerating, cl., etc.	$22.97	$22.50	$20.48
(B)	Sludge conditioning, and filtration:			
	Labor, 26 days per mo.; 1 man at $5.00 per day: 1 at $4.50; 3 at $6.75	$ 3.88	$ 3.72	$ 2.37
	Power ave. 0.88¢ per kw. hr.	1.81	1.81	1.81
	Alum 368 lb. per m. g. at 1.6¢ lb.	5.90	5.90	5.90
	Celite 431 lb. per m. g. at 1.47¢ lb.	6.35	6.35	6.35
	Oil, grease, tools	0.12	0.12	0.12
	Filter cloths, $150 every 4 months	0.18	0.18	0.18
	Maintenance and renewals	0.49	0.49	0.49
	Portion of general expense	1.80	1.72	1.10
	Sub-total, sl. cond. and filt.	$20.53	$20.39	$18.32

		July 1, 1928, to Sept. 30 1928 6.7 M. G. D.	Present Flow Ave. 7.0 M. G. D.	Plant Capacity 11 M. G. D.
			Est.	Est.
(C)	Sludge drying, exhaust gas burning, and storage of sludge:			
	Labor part time, 3 at $6.75 per day; 3 at $5.00; 2 at $4.50 per day	$ 4.55	$ 4.35	$ 2.76
	Power ave. 0.88¢ per kw. hr.	0.93	0.93	0.93

Sacks at 0.08	1.66	1.66	1.66
Gas for drier, at 17.5¢ per 1000 cu. ft	2.94	2.94	2.94
Gas for burning exhaust gas at 17½¢ per 1000 cu. ft	2.03	2.03	2.03
Miscellaneous, oil, and grease	0.04	0.04	0.04
Maintenance and renewals	1.04	1.04	1.04
Portion of general expense	1.27	1.22	0.77
Sub-total, sludge drying	$14.46	$14.21	$11.87

SUMMARY ITEMS (A), (B), (C)

(A)	Screening, aeration, clarification, chlorination	$22.97	$22.50	$20.48
(B)	Sludge conditioning	20.53	20.39	18.32
(C)	Sludge drying, storing, exhaust gas burning	14.46	14.21	11.87
	Total (A), (B), (C)	$57.96	$57.10	$50.67
	Less revenue from sale of sludge 1.2 tons per m. g. at $25.25 per ton (contract)	30.30	30.30	30.30
	Net operating cost per m. g.	$27.66	$26.80	$20.37

Investment costs appearing in comptroller's account, but not included in the foregoing cost data:

Water and gas extensions	$ 1,454.00
Irrigation pumps	7,528.88
Road	1,922.19
Pump house	3,705.77
Tearing out MacLachlin press	794.22
Condemnation proceedings, Rio Honda outfall	5,102.97
Outfall sewer to plant	23,520.90
Protection to creek banks	200.00
Road	206.45
Rio Honda outfall	122,717.70
Starting equipment (depreciation)	796.15
Sludge burying equipment (emergency)	3,350.43
Experimental work, included in an item of $9344.04 and estimated at	5,000.00
Total	$176,299.66

Operating costs appearing in comptroller's accounts, but not included in foregoing cost data:

Item 38–1 (salaries total $4627.10). Of this, $1923.60 was not for regular operation	$1,923.60
Mechanics and electricians (new work)	1,095.77
Salaries, city engineer	450.00
Salaries, experimental work (now ended)	514.23
Labor jobs, 1130–1131 (experiment)	246.81
Repairs to vehicles (sludge burying stopped)	124.80
Repairs and maintenance, $592.84, reduced because not normal monthly expense	242.84
Small tools (new construction)	19.23

Fuel, oil, gas, $250.05, mostly for sludge burial	200.05
Membership, C. S. W. A.	2.00
Item 38–2 Repairs, etc., $896.87, reduced to $412.50 since this was partly an annual repair and cloths last 4 months	484.37
Item 38–3 Entire item, method obsolete	2,789.31
Item 38–4 Repairs, $1085.12, not ordinary expense entirely	385.12
Item 38–5 Rentals, experimental	56.80
Items 38–6 to 8, inclusive, no longer practiced	909.30
Total	$9,444.23

Suspended and Settleable Solids in Worcester Sewage and Imhoff Tank Effluent

BY ROY S. LANPHEAR[1]

The sewage treatment plant at Worcester, Mass., consists of two grit chambers, two bar screens, Venturi meter, twelve double Imhoff tanks, four pairs of dosing tanks, four units of trickling filter totaling an area of 13.68 acres, four final settling tanks and sludge drying beds. Routine operating and analytical data are published in the Annual Report of the Superintendent of Sewers.

The object of this paper is to present the results of experimental work not included in routine data. An important factor in this connection is the industrial waste content of Worcester sewage, which includes pickling liquors, lime wastes, dye liquors, wool washings and slaughter-house wastes. All of these wastes are received at the sewage treatment plant in so-called doses. The combination of pickling liquors and lime wastes result in an excessive production of sludge in the Imhoff tanks. The lime wastes in particular carry large amounts of suspended solids which increase the difficulties of sampling. The colloidal matter content of the sewage varies considerably and affects the results of sewage treatment.

Suspended and Settleable Solids Content of Worcester Sewage

Average results of determinations of suspended and settleable solids in 24-hour composite samples of Worcester sewage are shown in the following table.

TABLE I

SUSPENDED AND SETTLEABLE SOLIDS CONTENT OF WORCESTER SEWAGE

	1926			1927			1928		
	Susp. Solids P. P. M.	Settleable Solids 1 Hour Cc. per Liter	Settleable Solids 2 Hours Cc. per Liter	Susp. Solids P. P. M.	Settleable Solids 1 Hour Cc. per Liter	Settleable Solids 2 Hours Cc. per Liter	Susp. Solids P. P. M.	Settleable Solids 1 Hour Cc. per Liter	Settleable Solids 2 Hours Cc. per Liter
Dec.		12.13	11.62	305	24.07	20.65	246	9.37	9.58
Jan.		15.12	13.87	279	16.03	14.54	255	11.14	10.55
Feb.		16.75	15.46	273	15.85	14.34	258	8.99	9.55
Mar.	209	10.07	9.90	265	14.86	13.63	279	12.37	11.80
Apr.	213	13.21	12.83	304	19.36	16.80	274	12.18	11.14
May	260	14.10	13.37	306	16.88	15.01	246	10.65	10.50
June	283	15.32	14.26	314	17.97	15.98	253	7.54	8.22
July	264	13.00	12.06	305	13.09	12.09	259	8.07	8.18
Aug.	304	15.79	14.03	298	11.12	10.59	276	10.14	10.19
Sept.	350	15.45	14.34	258	12.79	12.00	263	8.73	9.09
Oct.	322	20.03	17.48	298	11.66	11.26	362	14.70	14.03
Nov.	300	16.20	14.65	271	10.45	10.35	369	15.48	14.28
Average	278	14.76	13.65	288	15.06	13.74	275	10.57	10.39

[1] *Supervising Chemist, Sewer Department, Worcester, Mass.*

The sewage in 1927 contained slightly more suspended and settleable solids than in 1926; it also contained slightly more suspended solids than in 1928, and settleable solids were considerably greater in 1927. The suspended solids were determined by the Gooch method and the results include all matters in suspension. The settleable solids represent only those suspended solids capable of settling in the stated periods of time.

These results do not show the extreme variation and maximum quantities of suspended and settleable solids in Worcester sewage due to the presence of industrial wastes. Hourly and half-hourly samples of sewage contained maximum suspended solids contents of 1028 p. p. m.; 250 to 500 p. p. m. were common figures, while doses of lime wastes increased these figures to from 650 to 700 p. p. m. The 24-hour composite sample of sewage usually contains from 250 to 350 p. p. m. of suspended solids.

The settleable solids content of the 24-hour composite sample of weekday sewage, one-hour test, varied from 6 to 50 cc. per liter, while Sunday samples usually contain from 1.5 to 3.0 cc. Catch samples of sewage containing lime wastes generally have from 25 to 60 cc. of settleable solids per liter, one-hour test. The maximum result ever obtained in a catch sample of sewage, without particular attention to this determination but in connection with pH tests, was 110.5 cc. per liter, one-hour test and 94.5 cc. per liter, two hours.

Settleable Solids Content of Sewage, One-Hour Test, According to Days of the Week

The results of analyses of the 24-hour composite samples of sewage for settleable solids, one-hour test, averaged according to days of the week are summarized in the following table.

TABLE II

SETTLEABLE SOLIDS, SEWAGE, ONE-HOUR TEST. CUBIC CENTIMETERS PER LITER

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1926	2.17	12.34	18.05	18.60	21.31	18.61	11.15
1927	2.32	12.97	17.88	23.03	20.84	19.38	11.30
1928	2.48	13.55	15.38	14.75	11.89	10.31	7.34

There is a marked decrease in the quantity of settleable solids in the sewage during 1928 as compared with 1927 and 1926. Sunday and Monday results appear quite uniform throughout the three years.

Suspended Solids Content of Sewage According to Days of the Week

Similar results of the determination of the suspended solids in the sewage are presented in the following table.

TABLE III

SUSPENDED SOLIDS, SEWAGE, PARTS PER MILLION

	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
1926	121	306	312	312	315	307	264
1927	131	324	334	338	336	295	255
1928	147	322	337	314	289	293	247

* 1926—9 months.

With the exception of Saturday these data indicate that the week-day sewage content of suspended solids averaged from 320 to 340 parts per million.

Uniformity of Distribution of Suspended Solids in Imhoff Tanks

The sewage flow into the Imhoff tanks is regulated by gates, and there are no weirs at either end of the sedimentation compartments. The results of tests of each Imhoff tank effluent on ten different days, between 8 a.m. and 4.30 p.m., showed that the average suspended solids content of the effluent from each of the twelve tanks, expressed in parts per million, was as follows:

Average	87	77	88	81	82	76	83	78	84	82	78	82
		83				80				82		

Average even numbers or south battery, 80
odd numbers or north battery, 84

These results indicate a reasonable uniformity of distribution of sewage flow and suspended solids into the twelve tanks.

Precipitation of Solids in the Sample Bottles

Referring to the analytical results given in the last paragraph, some of these tests covered the time of day when strong sewage was received, yet the average of each day's test for the twelve tanks gave results which varied from 34 to 83 per cent of the result obtained for the 24-hour composite sample.

	Parts per million										
Average, 12 tanks	91	127	101	117	44	68	43	71	70	81	Ave. 81
24-hr. composite	110	180	160	170	128	120	126	152	102	112	Ave. 135

This experiment indicated that precipitation of solids was probably taking place, or colloidal matters were settling out, in the sample bottle after the addition of the individual hourly samples.

Tests of sewage samples carried on at the same time indicated a similar result but the difference was not nearly so great. The suspended solids content of markedly alkaline sewage was greater than of normal sewage free from lime wastes, but an attempt to show that these doses of wastes re-

sulted in an increase of suspended solids content of the Imhoff tank effluent was not entirely conclusive. The usual variation was such as to cover the range included when the alkaline sewage had been treated.

Precipitation of Solids in Sample Bottles Standing over Sunday, Imhoff Tank Effluent

The plant had been in operation but a few months when it was noticed that almost without exception the Saturday Imhoff tank effluent sample which had stood over Sunday always had a much higher content of settleable solids than samples of any other day of the week This condition has continued as shown by the monthly averages for Friday, Saturday and Sunday during 1928 in the following table.

TABLE IV

SETTLEABLE SOLIDS, IMHOFF TANK EFFLUENT

Cubic Centimeters per Liter, One-Hour Test

1928	Friday	Saturday	Sunday		Friday	Saturday	Sunday
Dec.	0.51	1.12	0.48	June	0.61	0.84	0.35
Jan.	0.65	1.70	0.31	July	0.58	1.06	0.38
Feb.	0.54	1.09	0.47	Aug.	0.58	1.21	0.41
Mar.	0.96	1.23	0.53	Sept.	0.45	0.86	0.34
Apr.	0.84	1.59	0.50	Oct.	0.72	1.31	0.31
May	0.53	1.35	0.65	Nov.	0.64	1.88	0.56

It is apparent that the Saturday results are much higher than those of Friday and Sunday probably due to the settling out of colloidal matter during the inital storage period of 24 hours. The same tendency is noted in the Friday and Sunday or any other day's samples, but to a lesser extent. This is well illustrated by the results of a test of morning catch samples of tank effluent, when six out of eight samples had 0.5 cc. or less of settleable solids per liter, one-hour test, while the other two had 0.2 and 0.4 cc., respectively; afternoon results during the same period showed that twelve out of fourteen samples had from 0.01 to 0.30 cc. while the other two had 1.9 and 2.9 cc., respectively. Undoubtedly the latter results were due to particularly strong doses of lime wastes and pickling liquors. The averages of the six and twelve samples were 0.03 and 0.12 cc. per liter, one-hour test, respectively. Results of tests of 24-hour composite samples on these days gave much higher results.

Increased Quantity of Settleable Solids Due to Additional Twenty-Four Hours' Standing—Imhoff Tank Effluent

The results of the previous test were obtained on Saturday, samples standing over Sunday. Another test of Imhoff tank effluent extended over a period of two weeks. The results are shown in Table V.

TABLE V

SETTLEABLE SOLIDS, IMHOFF TANK EFFLUENT

Cubic Centimeters per Liter				Cubic Centimeters per Liter			
First 24 Hours		Second 24 Hours		First 24 Hours		Second 24 Hours	
1 Hour	2 Hours	1 Hour	2 Hours	1 Hour	2 Hours	1 Hour	2 Hours
0.5	1.0	6.5	8.0	0.49	0.92	1.9	2.8
1.0	1.3	2.0	4.2	0.25	0.42	1.4	1.7
0.8	0.85	1.7	2.5	0.55	1.0	2.4	3.9
0.4	0.5	1.0	1.4	0.4	1.9	4.0	5.7
0.5	1.0	2.8	4.6	0.65	0.72	2.3	3.7
0.58	1.0	0.83	1.8	0.35	0.7	0.65	2.0
0.5	1.1	1.7	2.7	0.60	0.85	2.2	4.2
0.72	1.15	1.05	1.95	0.55	1.2	0.65	2.5
0.5	1.05	0.85	2.6				

There is a considerable increase in the quantity of settleable solids in the Imhoff tank effluent upon standing an additional 24 hours.

Character of Settleable Solids, Weekdays and Sundays, Imhoff Tank Effluent

The continued precipitation of colloidal matters upon standing is well shown by a comparison of weekday and Sunday results of settleable solids tests.

TABLE VI

SETTLEABLE SOLIDS, IMHOFF TANK EFFLUENT, CC. PER LITER

No. of	Weekdays			Sunday		
Samples	1 Hour	2 Hours	Increase	1 Hour	2 Hours	Increase
5	0.96	1.52	0.56	0.20	0.75	0.55
6	0.68	1.14	0.46	0.65	0.80	0.15
6	0.60	1.35	0.75	1.15	1.20	0.05
6	0.69	1.20	0.51	0.60	0.75	0.15
3	1.10	1.65	0.55	0.70	0.95	0.25
2	0.90	1.50	0.60	0.50	0.65	0.15
6	0.82	1.15	0.33	0.43	0.65	0.22
6	0.62	1.08	0.46	0.40	0.50	0.10
6	0.55	1.04	0.49	0.25	0.42	0.17
6	0.52	1.06	0.54	0.15	0.25	0.10
2	1.19	1.61	0.42	0.40	0.58	0.18
3	0.98	1.22	0.24	0.45	0.55	0.10
6	0.55	1.00	0.45	0.40	0.60	0.20
6	0.51	0.85	0.34	0.40	0.50	0.10
6	0.58	1.06	0.58	0.50	0.85	0.35
6	0.74	1.14	0.40	0.65	1.05	0.40
6	0.60	0.99	0.39	0.35	0.45	0.10
6	0.70	1.38	0.68	0.50	0.70	0.20
6	0.72	1.25	0.53	0.15	0.20	0.05

The increase in the quantity of settleable solids during the second hour is considerably greater in the weekday tank effluent than in the Sunday effluent.

Suspended Solids Content of Imhoff Tank Effluent. Comparison Catch Samples and 24-Hour Composite Samples

All of the data presented indicate that results of determinations of suspended solids in the Imhoff tank effluent will probably be lower in catch samples than in a composite sample. Determination of the suspended solids content of the tank effluent at half-hourly or hourly intervals on twenty-seven days during a period of five months gave the following results.

TABLE VII

SUSPENDED SOLIDS, IMHOFF TANK EFFLUENT, PARTS PER MILLION

Time																		
a.m.																		
8	46	56				46	62											
8.30		48				56		44										
9	78	50	64	50	46	50	54	46										
9.30		48		64	64		66	76										
10	70	66	94	80		130	84	84	68		40		42		24	50		124
10.30		78			144		88	86		90		86		68			100	
11	80	70	84	80		112	94	88							34	42		86
11.30		86		80	90		100	82	80	92	86	74	78	44			110	
12	62	74	120				90											
12.30				98	94			118										
p.m.																		
1	68	56	90			92	90	106	98	136	86		56	80				
1.30		64		86	90		76		110	148	108	84	82	102	80	102	196	110
2	68	90	106	58		76		124	88	148	116	112	122	80	92	84	154	88
2.30		92			94	82	112	116	96	144	128	66	76	54	90	120	100	112
3	56		56	100			118	98		128	126	88	88	50	108	140	106	64
3.30					56					94	114	88	74	54	88	124	102	64
4	70	116			76					100	100	92	126		80	96	138	126
Composite	120	74	110	148	128	152	166	124	150	124	118	182	146	118	132	120	120	120

The first part of this table presents results covering the morning and afternoon hours while the second part includes only two morning samples each day and a large proportion of the strong afternoon samples. The results of the 24-hour composite samples are generally higher than the apparent average of 24 hours of catch samples taken in proportion to the rate of flow. The morning-hour results indicate that the night results would be low, offsetting the afternoon results to a large extent.

Conclusion

1. Worcester sewage contains colloidal solids which coagulate upon standing so as to alter materially the content of suspended and settleable solids in samples of Imhoff tank effluent.

2. Uncomposited and unstored samples of Imhoff tank effluent must be used in order to obtain correct results for suspended and settleable solids.

3. The writer has arbitrarily adopted a standard of Imhoff tank effluent as 100 parts per million or less of suspended solids and 1 cc. or less of settleable solids per liter, one-hour test; these standards apply to the 24-hour composite sample. The average results for 1928 were 114 parts per million and 0.77 per cc. per liter, respectively. The data presented herein indicate that actually the suspended and settleable solids in Worcester Imhoff tank effluent are lower than is indicated by results of analyzed 24-hour composite samples.

Administrative Problems of Sewers and Sewage Treatment Plants[1]

BY P. F. HOPKINS[2]

The fact that sewers are buried in the ground out of sight and sewage treatment plants are usually in more or less out-of-the-way locations tends to create a lack of public interest in them. There is, too, an innate dislike in the average person's mind for the whole subject of sewerage. This attitude on the part of the public undoubtedly is reflected in the official tendency to be slack in the administration and care of sewer systems and sewage treatment plants, and to do only that which is absolutely necessary for their operation. The householder is not concerned with the sewer in his street so long as it takes care of his wastes; he never sees it and it never bothers him except in rare cases when it becomes clogged. On the other hand, he can see any defect in the surface of the street, and since its condition is important to him every day, he is not slow to complain when it needs attention. The sewage treatment plant is rarely visited by any but those responsible for its care, and even if it were visited, most people would expect to find a smelly, unsightly place, and would not realize that such a condition might be due to improper care in operation.

The net result of all of this is that nearly all administrators reduce the expense of sewerage operations to a minimum and do just what is necessary to keep sewer systems open and treatment plants from getting too objectionable. Money saved in this way can readily be allocated where the public can see the results—and we never have sufficient funds to satisfy the demands from our citizens for street work and similar services.

I do not mean to give the impression that we deliberately set out to neglect our waste disposal utilities, but we are all human, and we are likely to take care of those things which cause the most complaints, to the possible neglect of those which are not bothering us.

It can be truthfully said that the limiting factor in all municipal activities is the amount of available funds. If that were not true it would be a simple matter to administer a city's affairs. But since it is true, we are always on the lookout for ways to hold down operating costs. Only in the larger cities are we likely to find a separate sewer department whose first duty is to see that the sewers are properly inspected and maintained. Every town has some organization for handling street work, and it is quite common practice to delegate to the street department the maintenance of the sewers. There is no real objection to this way of handling work, and there are many reasons for such an arrangement, provided it is not

[1] *A paper presented at the Tenth Iowa Sewage Treatment Conference held at Iowa State College, Ames, Iowa, on Nov. 20, 21 and 22, 1928.*

[2] *City Manager, Mason City, Iowa.*

permitted to degenerate into just a case of handling complaints and stoppages. The average workman does not relish sewer work and probably has little conception of the sewer layout or the real function of the system. It is best, therefore, to select a few men who are intelligent and conscientious workmen who can be relied upon to do the actual work under proper direction. Pay them a little extra because of the nature of the work. They will soon develop what might be called the "technique" of clearing stoppages. They should be equipped with good sewer rods, plenty of hose, and various devices and tools for meeting any condition. It is just a foolish waste of money to send men out to do any kind of work without the proper tools. It is best to assemble all of this equipment on a special truck or wagon, so that when they are needed no time will be lost hunting for them, and when the trouble is located the tools needed will be there. Unless a crew is properly equipped and intelligently directed, more time can be wasted and useless work done in clearing a clogged sewer than in any other housekeeping function of the city—and in the meantime perhaps a block or two of basements are being flooded. If the taxpayer sees the gang aimlessly prodding away while his basement fills up, he is likely to judge the whole city administration by the way this particular job was handled; and it is surprising how long he will remember it.

No sewer system was ever constructed which did not at some time need attention. Systematic inspections will reveal tendencies to clog which can be quickly and easily cleared at this stage, but which will mean a real job if the sewer becomes entirely clogged. After the system has been checked a few times, it will be apparent where the stoppages are most likely to occur. These places can be given a little more frequent attention. Dead ends, new sewers with few connections, garages, wash racks, tree roots—all are frequent contributors to sewer stoppages.

It doesn't matter just what the organization for sewer maintenance work is—each town or city may handle it differently—just so someone competent is made responsible for the work. The city engineer, where available, is the logical man to have control over the sewer system and disposal plant. His knowledge of hydraulics, of the layout of the sewer system, and of sewage treatment cannot be duplicated in the ordinary workman. He will analyze the causes of the troubles and will take the necessary steps to prevent a recurrence. He realizes the danger of allowing untrapped garage wastes and wastes from wash racks to go into the sewers; he knows that roof drains and cistern overflows will overload the sanitary sewers; he will be able to detect the prevalence of these in any section; he knows how to keep records and how to interpret them.

Reports on sewer maintenance work need not be elaborate. Location of trouble, probable cause, any pertinent comments, and the cost of

clearing are sufficient. I am a believer in the value of visual records. A spot map showing the location of all sewer stoppages during the year may tell something that would not be apparent otherwise. You will be surprised at the number of repeaters. The removal of the cause will save you trouble and money.

During this short course you have all heard the operation of disposal plants discussed and the need of records stressed. It is obvious that a plant operator must be a man of sufficient intelligence and dependability to take these records and, from them, to judge the plant's operation. In addition to the records that indicate the efficiency of the plant operations, the administrative official wants also such records as will tell him how much sewage goes through the plant, individual pump performance and current consumption where pumping is necessary, labor costs, frequency of sludge withdrawals and the approximate quantities, when and why sewage is bypassed, when and why tanks foam and filters clog. He probably knows the daily water pumpage of the city (which has a direct relation to sewage flow) and will be able to detect any unusual relationship between this pumpage and sewage flow.

For the smaller towns which do not have technical advice available, it would be wise to arrange for periodic supervision by some competent engineer who can check up on operating conditions and advise your operator how to get results. This will not be beyond your financial resources and will save you money in the long run. The time required for such check-ups will be materially shortened if reasonable records are available. Aside from the actual value of good operating records, there is a bit of practical psychology in requiring an operator to write down each day certain facts concerning his plant. He will not continually put down in writing statements of plant conditions which he knows should not exist. The chances are that he will take the necessary steps to correct them and will soon take pride in being able to record truthfully "all's well." On the other hand, if there is no daily log of the plant, it is quite easy for him to contend that the bad condition "just got that way lately."

Just a word or two in closing, from the viewpoint of the administrator: he appreciates a neat-appearing plant that is operating well—one that he can feel safe in showing to visitors without having to find some excuse for the conditions found. He appreciates, too, the employee who has the initiative to see the things that should be done without waiting to be told to do them; who comes with constructive suggestions for ways and means for bettering the operations for which he is responsible, and who can back up his requests for equipment or improvements with concrete facts and arguments that will justify the outlay required. The employee must, of course, realize that his requests are only a part of many requests from other departments, all calling for the expenditure of funds. It is the

administrator's duty to weigh these requests as to their relative importance. Rarely can he grant them all; available funds again will limit his ability to provide.

It is standard practice in Iowa to levy special assessments on the cost of street sewers to the benefited property. Some cities may have conditions which make the cost of sewers far beyond the $3.00 per foot which by statute may be assessed. This means that the deficiency must be made up by the city. The cost of sewage treatment plants is great. The mill tax permitted by law will not always finance this cost and amortize it within the probable useful life of the plant. How and where to find legally the necessary funds is not the least of the administrator's problems connected with the important and vital function of caring for a city's sewage.

I have tried thus briefly to suggest to you some phases of this problem which are always present but which you, in your capacity as operators, may overlook, with the thought that you may be helped to see your work as only a part of the whole city's housekeeping; and that you may appreciate the administrator's viewpoint when he does not always provide the things which you feel are so necessary.

The Laboratory of the Sewage Treatment Plant

BY HENRY WEINER[1]

Designers of sewage treatment works often neglect unjustly the proper construction and equipment of the plant laboratory. It is one of the more important units in any plant and should receive the consideration commensurate with its importance, for upon the well-regulated research and control of sewage disposal depends the efficient working of the plant itself. The average designing engineer usually is unfamiliar with the chemist's needs in the arrangement and equipment of the laboratory. He may inspect sewage works laboratories, carefully noting their arrangement and various facilities; yet his incorporation of these in his proposed laboratory may not provide ideal conditions. The very laboratories he may have visited may have been poorly planned, and the possible improvement of the design of those laboratories may be evident to the chemist who works therein.

An attempt will be made in this paper to convey to the designing engineer and to builders of new sewage treatment works the general requirements of a complete, modern sewage laboratory from the chemist's viewpoint. The author's conclusions are based on observations during visits to various laboratories, academic, commercial and municipal, together with data based upon experience gained in the laboratory of the Baltimore Sewage Treatment Works.

Location

The laboratory should be in the administration building of the sewage plant, thus centralizing the factors of operation and control, unless the building is a considerable distance from the sampling stations. In the latter case a building, devoted solely to laboratory use, should be erected as near to the treatment units as is possible. In addition to making various determinations, the chemist must study and observe experimental units or other matters which require his personal attention. Too great a distance between the plant proper and the laboratory entails a loss of valuable time as well as a useless waste of energy.

Proximity of the laboratory to the plant units permits the minimizing of chemical work in the field, where unavoidable detrimental conditions may affect the accuracy of the results. The decomposition of samples, although at times negligible, presents one of the strongest arguments for a laboratory close to the points where the sewage is sampled. If the laboratory be made a part of a building, it should occupy the entire uppermost floor, where facilities for ventilation and lighting are the best.

[1] *Chemist, Baltimore Sewage Treatment Works, Baltimore, Md.*

Ventilation

Artificial ventilation is absolutely necessary in a sewage works laboratory. Aside from the necessity of ridding the room of obnoxious odors, the health of the workers is endangered by gases and lack of fresh air in a poorly ventilated room. In a pamphlet issued periodically by the Fisher Scientific Company (Vol. II, No. 1, p. 10) is the statement "... to thoroughly ventilate a laboratory in which a large quantity of fumes are present, the air should be completely changed every one and one-half minutes. For less severe condition, an air change every four minutes is satisfactory." The opening of windows for ventilation should be avoided. This procedure creates draughts, which are annoying to the man at the analytical balance.

Various systems of ventilation are now in use, ranging from a mere opening in the ceiling leading to the roof to intricate systems which comprise the regulation of heating and ventilating of entire buildings by means of air shafts, fans, and blowers. One simple system, quite effective, consists of the installation of a blower or series of blowers in the ceiling for the expulsion of impure air, with openings in the walls, near the floor, properly shielded from the elements and placed to avoid draughts, for the introduction of fresh air. There are also portable blowers, which may be inserted in the upper part of window frames.

Every laboratory should be equipped with a fume hood, through which dangerous and obnoxious gases can dissipate. The sides of the enclosure, with the exception of the glass windows and doors, are lined with an acid-proof asbestos compound. The hood terminates in a ventilator at the top, usually a tube leading through the roof of the building. Modern hoods are equipped with suction blowers, which tend to speed up the removal of the fumes.

Lighting

Analytical work, such as weighing, measuring and colorimetric work, requires that the source of daylight be the best. When the administration building is planned, the uppermost floor should be so arranged that the main source of light comes from the north and south. The windows on the other two sides admit glaring sunshine, one from the rising and the other from the setting sun, both of which are objectionable. Colorimetric work cannot be successfully done behind lowered shades. Such a procedure tends to impart a tinge of the color of the shade to the sample being studied.

Light from the north is the most uniform, consequently it is advisable to arrange the apparatus, where natural light is to be employed, at the northern end of the room. Light from the south is not so desirable as that from the north, but it is preferable to the direct sunshine from the east and the west. Light for use of the fine balance, burets and microscope is utilized to best advantage when it is diffused by frosted or the so-called "rough-

rolled" glass. Unnecessary eyestrain, due to the reflection of objects outside of the building, is thus obviated. Some laboratories admit light and ventilation through the roof in addition to that through the windows on the north and south, by means of skylights, making conditions of light and ventilation ideal.

The problem of artificially lighting the laboratory and its adjuncts should be assigned to the lighting expert. Fixtures which admit sufficient light and diffuse it effectively to exclude all glare are in use in modern laboratories and offices. Colorimetric work, when carried out in artificial light, is best accomplished when the so-called "Daylight" lamps are used. These are made especially for laboratory use, and are listed in laboratory supply catalogues.

Storage Space

Upon the institution of a well-planned storeroom depend the principles of order, efficiency and economy. The laboratory is thus kept in an orderly condition, the efficiency of the chemist is not impaired in searching for material needed in his work, and money is not wasted in purchasing supplies which may be hidden in some forgotten nook of the laboratory. It is therefore advisable to plan a storeroom of ample proportions with bins and adjustable shelving, so designed that every section can be carefully catalogued. The room should contain a safe for the storage of platinumware and other valuables. Ventilation and lighting should be considered, and ready access between the stock room and the laboratory should be provided.

The importance of arranging the material so that it can be easily found cannot be exaggerated. This can be accomplished by providing a series of shelves, separated into numbered bins. The material contained within these bins can be listed on a series of filing cards, each card to bear the name of the article, its designated section or bin, the quantity of material on hand, and the amount necessary for the normal operation of the laboratory.

Ordinarily, the laboratory is equipped with a complete set of apparatus and material necessary for routine work. As the supply decreases, replacements are made from the stock room. Each laboratory should determine the normal quantities of materials needed and should make replacements to the depleted quantities in the storeroom at frequent intervals.

The problem of storing the chemicals and supplies in regular use in the laboratory is solved remarkably well by the modern laboratory work table. These tables are equipped with drawers and cupboards in the lower section. These sections may be conveniently numbered or labeled and their contents recorded. Acid-proof shelves are provided at the rear of the table top to hold bottles of commonly used reagents.

With the possible exception of an occasional shelf for water stills and

large containers of distilled water near the sink, the laboratory walls should be kept free from shelving. Cabinets may be built or purchased instead of using an array of shelves along the walls. These cabinets should be used to store apparatus not easily kept in the space provided by the table drawers and cupboards. They should be judiciously placed about the laboratory in order to provide the greatest accessibility. They should contain glass doors in the upper section and drawers in the lower part.

The Laboratory

The problem of arranging the laboratory to suit its particular type of workers is best solved when the kind of work to be done is considered. The research chemist prefers to work alone. He requires a laboratory divided into small, individual rooms, each equipped for the type of research conducted, with all rooms united by a large room as the main laboratory. The commercial chemist prefers a laboratory built according to the requirements of the research chemist, except that each of the small rooms be equipped with material necessary to conduct a particular type of determination. The sewage laboratory is best planned when the requirements of both groups of chemists are considered, since sewage investigations combine the necessity for research work and the analyses and tests for the control of operation.

Sewage disposal is to a great extent a biological phenomenon, therefore a completely equipped laboratory should be provided with facilities for biological research in addition to the requisites for conducting chemical investigations. The technique of the bacteriological worker varies greatly from that of the chemist. The difference in character of the work necessitates the division of the laboratory into two distinct units, bacteriological and chemical. The two laboratories should be adjacent and easy access to each made possible through a common entrance.

The delicate analytical balances of the chemical laboratory are easily affected by vibration, the least jar throwing them out of adjustment. It becomes imperative, therefore, to select a place for the balance where vibration is reduced to the minimum. As the walls of the building are usually free from vibration, a firm shelf, built close to a window, can be used as a support for the balance. This shelf should be of the same size a the laboratory table and preferably acid-proof. Sufficient space should be provided near the balance for desiccators or other dehydrating apparatus. Some laboratories provide specially constructed rooms, designated as balance rooms, free from vibrations and draughts.

The laboratory table is the work bench of the chemist, and should be of the best type obtainable. This is not necessarily the most expensive type, although the initial expenditure on this kind of furniture should not be spared. An acid-proof wood top table is quite as satisfactory as the ex-

pensive acid-resisting "soapstone" top type, with the added advantage that there is less breakage of glassware. An excellent table for all laboratory purposes combines the advantages of acid-resisting wood and soapstone. The top is of acid-proofed wood, and a gutter of ample dimensions at the rear of the table top is of soapstone, leading to a soapstone sink at the extreme end. Outlets for water, illuminating gas, steam, air pressure and suction should be installed at convenient intervals, either upon the table top or upon the wall against which the table is placed. The taps for these outlets can be obtained in one fixture, the handle of each tap bearing the name of the commodity furnished, indelibly stamped thereon. By this arrangement of outlets and with the gutter, which slopes gradually to the sink, the worker has access to a sink at any part of the table, a convenience greatly appreciated by the chemist.

The completely equipped laboratory should contain two constant temperature rooms. These are rooms, well insulated against heat and cold, wherein a constant, predetermined temperature is maintained by thermostatic control of heaters and refrigerating units. It is advisable to maintain one of these rooms at a constant temperature of 20° C. while the other may be adjustable to the varying temperatures desired for any particular type of research.

Sufficient well-lighted space should be provided for offices, with a large room containing desks for each of the chemists, and a smaller room reserved for the head of the laboratory force as his office and consultation room.

Office records and work sheets can be conveniently kept in loose-leaf binders while being used, and may be stored away for reference in carefully indexed filing cabinets. Metal filing cabinets, to suit the size and type of records used, can be installed.

To facilitate calculations and to effect a considerable saving of time, as well as to insure accuracy, a calculating machine should be provided for every large laboratory.

A part of either of these offices may be used for a library, if there is not a separate room for this purpose. One side of the room should be reserved for sectional bookcase compartments. A part of the room should contain space for journals, magazines and printed reports. Sewage journals and publications treating of sewage disposal, which are issued periodically, are best preserved for future reference by binding them.

As a rule the chemist at a sewage plant should take care of first-aid treatment. First-aid equipment should be installed in the laboratory. Suggestions covering needed equipment can be readily obtained from any hospital and are gladly furnished by medical supply houses.

Some consideration should be given to the finish of the floors and walls of the laboratory. It should be pointed out, however, that if the walls are finished with glazed tile they may be easily cleaned and the necessity of

occasionally painting the walls, with the attending disorder, is obviated. Furthermore, glazed tile is unaffected by chemical fumes which are ever present in the laboratory.

Figure 1 shows the plan of laboratory rooms designed to serve the needs of a sewage plant of a large city. The smaller plant may use this as a model and modify the facilities noted to suit the size of the plant, although smaller sewage works, which feature research work, may find a laboratory of this size quite suitable.

Laboratories should be constructed to meet the Board of Fire Underwriters' specifications and, wherever possible, should be built of fireproof material. To safeguard further the laboratory against casualties due to

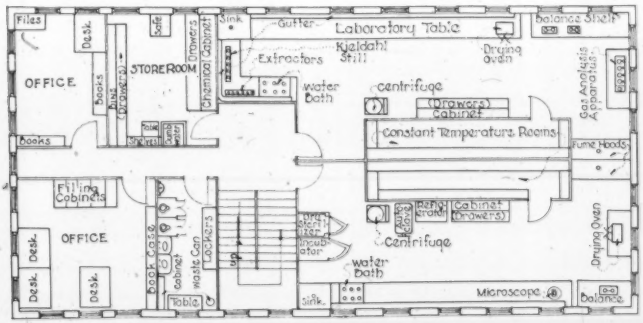

FIG. 1.—Floor Plan of Laboratory for Sewage Treatment Works.

fire, extinguishers, preferably of the type used for fighting electrical fires, should be provided. The laboratory plumbing should be much the same as in any other building, except that the traps and drains leading from the sinks should be of heavy lead pipe. As many clean-outs as possible should be inserted in the waste line in order to facilitate cleaning. Some laboratories prefer exposed plumbing so that repairs may be made without tearing the floor or walls away to expose the pipes, although this type of installation is less pleasing in appearance.

Apparatus

Expense should not be spared in procuring the best type of permanent apparatus obtainable. The initial expenditure for the higher priced apparatus more than justifies itself when we consider the repairs, delay in replacements and final discard of the inferior, cheaper type.

Apparatus which contain heating elements should be restricted, if possible, to the electrical type. Thermostatic control of air baths, water

baths and incubators is more satisfactory electrically than by means of cumbersome, intricate and uncertain gas regulators. The superiority of electrically heated apparatus over that heated by gas needs no mention. Cleanliness and efficiency fully justify the additional expense.

Space does not permit the enumeration of all the necessary apparatus for complete equipment of the laboratory. Mention will be made, however, of the major pieces of apparatus, which constitute permanent fixtures in the laboratory and with which the chemist should be provided. With the major apparatus as a nucleus, the chemist can be supplied with the necessary glassware and minor appurtenances in a comparatively short time. Added to this list of apparatus, which appends this article, is a list of books on sewage disposal which should form the beginning of a library and which should be found in every sewage works laboratory of any size. Chemical manuals, books on laboratory and analytical procedure, and handbooks are purposely omitted from the list. The chemist must use his own discretion in procuring the type of literature that best suits his needs.

The approximate cost of the apparatus listed is $5000. Allowing a like amount for the equipment of the offices, library and minor apparatus, the cost of fully equipping a laboratory is small when compared with the cost of the entire sewage works. Yet the value that may be derived from this expenditure is considerable.

We gratefully acknowledge the assistance of C. E. Keefer, Engineer of Sewage Disposal, and G. K. Armeling, Superintendent of the Baltimore Sewage Treatment Works, in preparing this paper.

APPARATUS NECESSARY FOR FULLY EQUIPPING A LABORATORY FOR SEWAGE DISPOSAL INVESTIGATIONS

Laboratory tables*	Kjeldahl Supports with Heaters
Fume Hoods*	Kjeldahl Distilling Outfit
Cabinets*	Incubator
Analytical Balances*	Dry Sterilizer
Water Baths*	Autoclave (Steam Pressure Sterilizer)
Drying Ovens (Air Baths)*	Water Still
Centrifuges*	Gas Analysis Apparatus
Extraction Support and Accessories	Refrigerator
Muffle Furnace*	Microscope and Accessories

* Apparatus should be duplicated, one for each laboratory.

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Industrial Wastes and Stream Pollution

Disposal of Industrial Wastes[1]

By John D. Rue[2]

It is to me particularly significant that the subjects of industrial waste and means for its disposal are occupying a place of increasing importance and interest in your minds. In some industries, notably meat packing, complete utilization of all raw material and elimination of waste has become proverbial. In others, however, the waste is still large and problems related to its disposal are many and difficult.

There are people to whose mind failure to find means for the complete elimination of waste seems to be an indication of wilful neglect. But good business men do not wilfully neglect opportunities to make money. Not long ago, I heard one of the most prominent administrators in the pulp and paper industry make a statement in the presence of several State sanitary engineers, to the effect that in the waste of the industry was to be found the profit which in many cases would spell the difference between profit and loss for the operator. The profit, however, can come only after long and patient and sustained application of technical and scientific talent to the investigation of the problems involved.

However difficult the problems of waste disposal may be, those problems still exist in most industries and must be faced so long as we have the much-desired growth and expansion of industry. The great question is, how can those problems be met and solved to the best interests of all concerned?

It is my good fortune to be connected with the pulp and paper industry and I know that I can speak more intelligently if I confine myself chiefly to my subject as it relates to that industry.

We are all accustomed to think of the installation and operation of municipal water supplies as large undertakings and I do not wish to minimize either their size or importance. You may be interested, however, if I remind you that for just one pulp and paper plant in our own State, the plant with which I am connected, the daily water supply is 30 million gallons. For the purification and filtration of such a supply there is required a plant larger than the combined installed capacity of any four cities in North Carolina.

That one plant has over 1300 employees and requires 1000 more in the production of its raw materials. It is estimated that upon it some 25,000

[1] *Address at Annual Banquet N. C. Sewage Works Association, Raleigh, N. C., Nov. 20, 1928.*

[2] *Director of Research, Champion Fibre Co., Canton, N. C.*

people are directly or indirectly dependent for a livelihood. Involved in its operation are the production and use of 800 tons of coal daily, the operation of 30,000 h. p. in steam-producing units, the use of 12,000 electrical horse power and the handling of in- and outbound freight to the extent of 2000 tons daily.

A single steam power unit has recently been put into operation which evaporates 300,000 pounds of water per hour, or about 800,000 gallons per day. The water evaporated each day for the production of steam for the entire plant aggregates nearly two and one-half million gallons.

The wood is cut into chips and charged into huge pressure digesters holding in some cases as much as 25 cords each. It is cooked with caustic or acid liquor. The water required for the cooking liquors amounts to a daily total of nearly one million gallons, a large proportion of which is evaporated in order that the chemical may be recovered and used again. Over one million gallons are used daily to wash the pulp thus obtained by cooking the wood.

The pulp is converted into paper by suspending the fibres in water so dilute that only one-quarter to one-half pound of fibres is found with each 100 pounds of water. The suspension is run out on to a wire cloth. The water drains away leaving a mat of wet fibres which is sucked and pressed and finally steam-dried to the sheet of paper with which you are familiar. The water required at our plant to carry the pulp on to the paper forming wire screens aggregates some 13 million gallons per day.

Furthermore, water is used as a carrier for the pulp, which is pumped from point to point within the mill, suspended in water. For that purpose 25 million gallons per day are required.

It is only by repeated reuse and continued recirculation of the water within the plant that the total volume is reduced to its existing amount.

The important wastes from a pulp and paper mill may be briefly summarized. First, there is the paper-making stock, which includes chiefly fibre and clay. In the repeated charging and discharging of the water carrier or conveyor with paper stock a small proportion of the fibre escapes recovery and finds its way into the mill effluent. That constitutes the form of waste universally met with in the industry inasmuch as it is common to all types of pulp and paper manufacture. Because of its milky appearance the water suspension is popularly called white water.

Next there are the wastes which are formed in the cooking of the wood and in the subsequent bleaching of the pulp. Those wastes are removed when the pulp is washed and we may conveniently call them washing wastes. They are common to all chemical pulp mills and to all pulp bleaching plants.

Again there are the lime sludge wastes which are formed when the cooking liquors in the alkaline pulping processes are treated with lime water just prior to their use for cooking the wood. Chemically, they are practically the same as ground limestone.

While you may be interested in what these wastes are, you are no doubt far more interested in what has been done to reduce or eliminate their discharge from the mill. I could tell you much about what has been accomplished, especially during recent years. I shall have time, however, for only the briefest mention of a few of the most outstanding efforts and their results, and then for an indication of the systematic and orderly manner in which the pulp and paper industry is applying itself on a nation-wide scale to the solution of the problems which still remain unsolved or only partially solved.

One of the most difficult wastes to dispose of is the washing waste which contains the cooking chemicals and the portion of the wood which has been dissolved in liberating the pulp. The cooking liquor in our plant amounts to one million gallons per day. It is diluted by another one and one-half million gallons of necessary wash water. It is universal practice for pulp mills to evaporate the water and to incinerate the concentrated residue. Over 7000 gallons of water must be evaporated for every ton of pulp made. The cooking chemical in modified form is found in the incinerated ash and is reconverted into its normal form. A very large proportion of the cost of an alkaline pulp mill installation is found in the plant devoted to the disposal of the washing waste, incident to the recovery of the cooking chemical.

A problem even more difficult than the disposal of the alkaline washing wastes is the disposal of the acid washing wastes from the so-called sulphite pulping process. This liquor is very corrosive. Some progress has been made in the disposal of this waste. A portion of our sulphite waste is being converted into adhesive and other by-products having a limited commercial value. It would take a small chemical dictionary to contain a list of the various products that have been made experimentally by the army of investigators in the industry. Among the products are alcohol, road binders, linoleum cements, foundry core binders, dyes, fertilizers and many others. Except possibly alcohol, none of them nor all of them together can supply a market adequate to absorb the quantity of product that would result if all the sulphite liquor from the pulp mills were converted into them. Even though alcohol were produced as it was in some twenty plants in Sweden at one time, the problem of disposing of the waste would not be materially reduced.

The lime sludge has under favorable circumstances been disposed of for agricultural purposes. In other cases it is allowed to accumulate on idle land. In still others, it is discharged into the mill effluent. In our own North Carolina plant the lime sludge is burned in a huge rotary kiln and reconverted into lime which finds use within the plant. No lime sludge leaves the plant.

It is perhaps fortunate that the white water waste problem, the problem which is universal in the industry, is one of the less difficult ones to combat. Especially during the last four or five years, tremendous advance has been

made in the reduction of the quantity of stock allowed to escape into the mill effluent.

Thousand of dollars each year are being expended by our own company and by companies throughout the industry for improved equipment that will insure by filtration and sedimentation a more complete separation and recovery of the paper stock before the waste water is released from the mill.

The pulp and paper industry is not yet satisfied with what has been accomplished and is facing the remaining problems in a broad-minded way and on a national scale.

Realizing the seriousness of the problem and stimulated by the activities of various organizations demanding stream improvement, the American Paper and Pulp Association at its annual meeting in February, 1925, authorized the appointment of a national committee on waste utilization and stream improvement. That committee is composed of fourteen representatives of the industry, five State sanitary engineers, one member of the United States Forest Products Laboratory Staff and the association's engineer; the last is a former State sanitary engineer now devoting his entire time to the organization and prosecution of this work for the association.

Please note that the membership of this committee includes five State sanitary engineers. I happen to be Chairman of that Committee and it is an impressive sight to see the representatives of the industry and the State gather around a common table to discuss freely and frankly the problems of waste so vital to both.

I believe we are entering upon a new era in the history of the relationship between industry and those State authorities charged with maintaining the streams in a condition of maximum utility to the community.

It was Charles Lamb, I think, who exclaimed as he and a friend passed a stranger, "I hate that man." To his friend's remonstrance that he did not even know him, he replied, "Of course, I don't know him; if I knew him, I couldn't hate him." Knowledge is the first requisite to a clear-minded approach to these complex problems of waste disposal; knowledge by all parties concerned of the magnitude of the problem and of the wide variety of factors and interests involved in a search for an adequate solution.

The State of Pennsylvania was a pioneer in the development of a coöperative and sympathetic method for accumulating the knowledge which constitutes the basis for an intelligent search for a solution of the problem involved.

Let me quote from a paper presented March 25, 1927, by Dr. Theodore B. Appel, Secretary of Health and Chairman of the Sanitary Water Board of Pennsylvania to the Philadelphia Section of American Society of Civil Engineers. Speaking of industrial waste, he says:

"The products deleterious or otherwise thrown into the waters of the State by industry are so varied that no general line of treatment can be devised, but each industry must be investigated individually. In addition, at present in many of these industries

whose waste is an injurious contamination no practical plan for treatment exists and I would emphasize that word *practical*. The plan of treatment must be effectual in that it removes all or at least a sufficient amount of the injurious waste to make the effluent harmless and unobjectionable, but it cannot throw too large a burden on the overhead expense of the industry, lest those industries on a competitive basis with others more favorably situated can no longer compete and their employes are thereby deprived of their livelihood or in others where the competitive feature is not so pressing the increase of the price of the manufactured article to the consumer passed on by the increased overhead be so great as to place the necessities of life beyond the reach of the common citizen. The problem then is to bring about purification of the streams after due study of their present and possible future uses, with careful balancing of *all* the interests involved. It must in the final analysis become a study of the individual streams."

And further let me quote from the Report of the Sanitary Water Board to the Governor of Pennsylvania, December 31, 1926:

"Sanitary conservation, therefore, does not mean the treatment of all polluting matter to a high degree, but rather a determination of the pollution load which each stream or part thereof can inoffensively and harmlessly assimilate, if any, and then a utilization of the stream to that extent and a requirement for the treatment of all excess pollution load to such a degree as to maintain the stream in a condition fit and suitable for its most advantageous public use.

"The Board, therefore, believes and has put into practice the policy of coöperating with industry in scientific study of industrial waste disposal and toward finding methods of treating such wastes to produce an effluent capable of inoffensive assimilation in the streams and at a cost which will not place our Pennsylvania industries at a disadvantage in competition with like industries in other States.

"Excessive cost of manufacture of finished articles from raw materials is ultimately passed on to the public when they purchase goods and hence it is to the public interests to establish an equitable balance in such matters."

The Pennsylvania policies have been successfully applied in that State in coöperation with the tanning and pulp and paper industries and with others.

The validity of those policies is being favorably demonstrated also in other States such as Wisconsin, Ohio, Michigan and elsewhere. Our own State of North Carolina has recently concluded operating arrangements with the pulp and paper industry of the State based upon those same policies.

The American Paper and Pulp Association through its National Committee on Waste Utilization and Stream Improvements and its engineer is working along similar lines.

I cannot too strongly emphasize, however, that while much is being accomplished in the extended application of known feasible corrective measures, some of the most difficult problems still remain to be solved and that even under the favorable conditions which are being established through coöperative policies, and even with the application of intensive and extensive technical and scientific talent, practical solution may not be found as early as we all desire. Whether the results are quick or slow in arriving one thing is certain and that is that both industry and State are becoming more and more committed to the policy of team work in this matter.

Editorial

The Federation

The most positive proof of the need for the Federation of Sewage Works Associations is furnished by the rapid growth of new local associations and conference groups throughout the country. It is difficult to keep pace with their formation. Each issue of THIS JOURNAL has included notices of the affiliation of from two to six of these associations with the Federation.

These associations extend from New England to California, from Wisconsin to Texas. Specifically, they comprise the following, all of which are now members or will apply for membership in the near future: Arizona, California, Central States (Illinois, Indiana, and Wisconsin), Iowa, Maryland, Missouri, New England, New Jersey Conference, New York, North Carolina, Pennsylvania, Texas, and Virginia. A section from the U. S. Public Health Service is also being organized.

The enthusiasm shown in some of these groups is remarkable. The California association has had two meetings since its organization in 1928; it now has nearly 200 members, and it has published a very creditable report containing the papers presented at the first annual meeting last October. The Texas and North Carolina groups have also published proceedings of their 1928 meetings. The Central States Association is growing rapidly. Pennsylvania, Iowa, Missouri and Maryland groups have had very successful meetings within the past year. Arizona, New England, Virginia and New York Associations are meeting this month (April). The New Jersey Conference met during the meeting of the New Jersey Sewage Works Association at Trenton in March.

This activity indicates that there is widespread interest in the development of a new national organization which may accomplish for the science of sewage disposal and sewage treatment what the American Water Works Association has accomplished for the science of water supply and water purification. As yet there are no definite plans beyond the desire to expand and strengthen each local organization and to keep the aims of all groups in harmony, so that when the time comes for more closely knit organization the various units may coalesce smoothly.

The SEWAGE WORKS JOURNAL is the only medium of exchange common to all groups. The publication of proceedings and papers selected from the programs of local associations is essential for the development of mutual interest in and appreciation of what is being done in parts of the

country distant from our own section. The success of the JOURNAL and the future of the Federation depend to a considerable extent upon the accuracy and adequacy with which the work being carried on in certain local groups is reported to others.

This requirement places certain responsibility upon the representatives of the local groups. They should send proceedings, papers and news to the JOURNAL promptly. This has not been done heretofore. The Editor has had to solicit numerous papers from sources other than the representatives of the local associations.

Those interested in the future of the JOURNAL should pause to realize our good fortune in having the financial and technical aid of The Chemical Foundation. No expense has been spared to provide the best possible paper, publishing facilities and all other services necessary for the material needs of the JOURNAL. Our advertisers are also essential now and will be even more so in later years.

The financial aid we now have makes it possible to send the JOURNAL to the members of Sewage Works Associations at one-third the cost of a direct subscription. This saving is an important incentive for the affiliation of local groups, particularly when they realize that such affiliation will not in any way detract from or injure their local value. The opportunity to present results of research to all other local groups is undoubtedly an advantage, and a privilege not enjoyed heretofore.

The summation of these thoughts is, briefly: For a long time we have been discussing, planning and forming this Federation and THIS JOURNAL; now that the Federation is organized and the JOURNAL is launched, through the help of The Chemical Foundation and our advertisers, we should take advantage of our present opportunities to build up our local organizations to the point where the Federation and the JOURNAL shall be independent and self-supporting; we should exert special efforts to secure and publish papers on research and operating problems.

Finally, may we have more critical discussions of the new theories and viewpoints expressed in the original articles, and particularly criticism and suggestions as to improvement of the JOURNAL?

Trends in Sludge Disposal

The disposal of sludge is still the paramount problem in the treatment of sewage. Recognition of this fact is afforded by consideration of the great variety of processes and procedures for the dewatering of sludge. In this issue several contrasts are presented, drawn from practical operating experiences in the United States, England and Germany.

The drying of activated sludge on sand beds at Tenafly is the first application in this country, on an appreciable scale, of a procedure that has been in common use in England. Excess activated sludge at Sheffield and Reading has been dried on open-air sloping ash beds, but large areas are required, varying from 3.5 to 7.0 square feet per capita. Further experience at Tenafly should indicate whether it is possible to reduce this liberal area by enclosing the beds under glass. The results will be watched with interest. American practice in dewatering activated sludge on sand beds has usually included preliminary digestion of the activated sludge mixed with settled sludge from preliminary tanks. The largest plant of this type is the Chicago North Side Treatment Works.

The production of fertilizer from activated sludge is described by Mr. Wyman in this issue. Milwaukee and Pasadena are the largest plants of this type in the United States and there are none in other countries. The Pasadena results show high costs of operation but considerable improvement over the previous unsatisfactory scheme of trenching and burying.

A number of years of operating and cost data will be necessary in order to afford comparison of the two major schemes adopted in the United States for dewatering activated sludge.

The disposal of settled sludge is accomplished in various ways. The Worcester and Syracuse plants use totally different procedures, but the local conditions at the latter plant are unique and not representative of usual practice. The Imhoff tank, sand-bed procedure is predominant in America, although separate digestion with heating of sludge and collection of gas is enjoying considerable development. German practice also shows a decided trend toward heating and gas collection. In general there is more similarity in the lines of development in America and Germany than in America and England or England and Germany. This fact has recently been noted by Dr. Bach, Chemist of the Emschergenossenschaft, in a letter to the Editor of *The Surveyor*. Dr. Bach made the following statement:

"As to the sludge disposal question in general, it is difficult to understand why the advantages connected with sludge digestion are as yet so persistently disregarded in England, although it has now been in use for twenty years or so with excellent results in hundreds of sewage disposal plants in Germany and America, and in these countries is regarded almost as a standard method. Why this worry with lagoons, sludge presses, land burial, and similar unpleasant and troublesome disposal methods, when you can turn the sludge in a technically reliable manner and free of nuisance by a two-story or separate digestion tank into an inoffensive, inodorous, well-drained product, small in volume in comparison with the highly offensive fresh material?"

This viewpoint is somewhat narrow, for there are several examples of sludge digestion on a large scale in England, notably at Birmingham and Bath, but in the main it is true that British practice has not accepted sludge digestion so unreservedly as it has been accepted in Germany and America.

British practice was well described by Mr. Garner, Deputy Chief Inspector of the West Riding Rivers Board, Wakefield, in a recent paper before the Association of Managers of Sewage Disposal Works. An abstract of his paper appears in this issue.

One phase of German practice is being developed by Dr. Max Prüss, whose publications are abstracted in this issue.

Research on sludge digestion and disposal is progressing so rapidly at the present time that it is difficult to predict the probable trend of development in the next five or ten years. It is certain that more complicated mechanical means will be used to obtain controlled, intensive digestion.

Mechanical equipment will also supplant hand methods for dewatering and drying. It is probable that German, English and American practice will tend toward greater uniformity in the future. It is quite unlikely, however, that there ever will be even moderate standardization in sludge digestion and disposal.

Proceedings of Local Associations

Texas Water and Sewage Works Association Eleventh Annual Meeting

Texas A. and M. College and Bryan, Jan. 23–25, 1929

The Eleventh Annual Texas Short School for Water and Sewage Plant Operators was successfully completed during the period of January 14–25 at Texas A. & M. College and Bryan, Texas. The sessions were divided into two sections: (1) Elementary or Laboratory, January 14–22 at A. & M. College, and (2) General and Convention, January 23–25 at the LaSalle Hotel in Bryan, five miles distant from the College.

The total attendance for the entire week approximated two hundred, and the interest in the Laboratory section was beyond expectations, averaging thirty in attendance during the ten days.

The Committee was fortunate in procuring lecturers for the school. Sewage research was a subject of live interest during the sessions and much discussion was provoked through the leadership of Dr. F. E. Giesecke and Professor E. W. Steel of the Sewage Research Station of A. & M. College, and V. M. Ehlers, Chief Sanitary Engineer of the Texas State Department of Health. Activities in the field of sewage research in Texas during the year were summarized as follows:

(1) A booklet entitled "What's Happening to Our Texas Streams" was prepared and made available for free distribution in Texas through the Chemical Foundation, Inc., New York City.

(2) Various agencies were induced to subscribe funds for assisting in the maintenance of the sewage research station at Texas A. & M. College.

(3) Affiliation of the Sewage Division with the Federation of Sewage Works Association was completed. (See Constitution below.)

(4) A bulletin on "The Dunbar Sewage Filter" was prepared for distribution by E. W. Steel and P. J. A. Zeller of the Texas A. & M. Sewage Research Station.

(5) Legislation in support of better stream protection and sewage research has been encouraged.

Upon report of the Committee on Nominations, the following officers were reëlected for the year 1929:

J. Z. Martin, Breckenridge, *President;* W. H. Deaton, Waco, *First Vice-President;* Bud A. Randolph, Houston, *Second Vice-President;*

L. A. Grimes, Abilene, *Third Vice-President;* J. R. John, Dallas, *Fourth Vice-President.*

Upon call of the President, M. Z. Martin, an Executive Committee meeting was then held and the following additional officers reappointed: V. M. Ehlers, Austin, *Secretary;* E. G. Eggert, Austin, *Treasurer;* and Ella G. White, *Editor.*

The Secretary was instructed to proceed immediately with arrangements for having the proceedings of the 11th Short School printed and to attend to such other routine matters as might be necessary.

Invitations for the 12th annual short school were received from a number of cities, including Abilene, Bryan, College Station, Waco, Austin and Lubbock. The choice of the Convention lay with Abilene, upon the statement by L. A. Grimes, Superintendent of the Water and Sewer department of that city, and substantiated by other Abilene officials that all requirements of the Executive Committee would be complied with regarding adequate provisions for the meeting. Mr. Grimes was selected as general director of the 12th school and Dr. E. P. Schoch of Austin, Director of the Laboratory Section.

Dr. E. P. Schoch presented a brief report covering a canvass made by him of the membership for expressions regarding the desirability of reorganizing the Texas Section as the Texas Water Works Association, or other arrangement by which attendants of short schools might be relieved of the payment of membership dues assessed by the Southwest Water Works Association. After discussion, a resolution presented by Dr. Schoch and amended by J. Bryan Miller was presented in the following form and and adopted:

Resolved, that the President, J. Z. Martin, appoint a committee of five, to include Dr. E. P. Schoch and the President, L. A. Quigley, C. C. Hays, and L. A. Grimes to investigate fully and report on the advisability of a rearrangement of the Texas Section as a separate unit from the Southwest Water Works Association, or provisions for holding short schools for water and sewage plant operators separately from meetings of the Texas Section of the Southwest Water Works Association.

A suggested constitution for the Sewage Division was presented by W. S. Mahlie, Chairman. After explaining that it was prepared primarily to permit unqualified affiliation with the Federation of Sewage Works Associations it was accepted and approved as follows:

Sewage Division-Texas Section, S.W.W.A.

CONSTITUTION

ARTICLE I

NAME

The name of this organization shall be the Sewage Division of the Texas Section of the Southwest Water Works Association.

ARTICLE II

OBJECT

The object of this organization shall be the advancement of fundamental and practical knowledge concerning the nature, collection, treatment and disposal of sewage and industrial wastes; and the design, construction, operation and management of sewage works through the coöperation of its members and other persons or organizations of similar interests. It shall also promote the protection of public waterways in coöperation with water works officials and others interested in waterways sanitation.

ARTICLE III

MEMBERSHIP

The membership of this Division shall consist of members of the Texas Section who desire to become more closely affiliated with others interested in sewage works problems, such members to be admitted without further dues for the Division, but if such members desire the *Sewage Works Journal* published by the Federation of Sewage Works Association, upon the payment of $1.00 subscription they will be entitled to such *Journal*. Other persons also desiring to become associated with this Division may do so upon the presentation of satisfactory evidence and upon payment of the annual dues.

ARTICLE IV

ORGANIZATION

The affairs of this Division shall be conducted by the Executive Committee, consisting of the President, the Secretary, and the Treasurer of the Texas Section, the Chairman of the Sewage Division, and the Chairman of the standing committees of the Sewage Division. The officers of this Division shall be the Chairman, the Vice-Chairman, the Secretary-Treasurer and the Editor, such officers to be designated by the President of the Texas Section and by any suitable manner of voting.

ARTICLE V

TENURE OF OFFICE

The officers of this Division shall serve one year and be eligible for reëlection.

Dr. Karl Imhoff to Visit Texas April 25

According to recent communication to Mr. V. M. Ehlers, Chief Sanitary Engineer, Austin, Texas, announcement is made that Dr. Karl Imhoff, internationally known authority on sewage purification and inventor of the famous Imhoff tank, is scheduled for a visit in Texas beginning April 25.

Dr. Imhoff's interest has been attracted to Texas through the extensive stream pollution control work, sewage purification, and study and research. Tentative plans include invitation for Dr. Imhoff to address the American Society of Civil Engineers at their spring meeting scheduled at Dallas, April 24–26. Other conferences and visits of inspection to some of the unique and modern sewage purification works in Texas will include the following towns:

Dallas—Experimental units of activated sludge, separate sludge digestion, degasification, Imhoff settling, sprinkling filters, grease skimmers.

Fort Worth—Imhoff, sprinkling filters, mechanical clarifier, new activated sludge units under construction.

Cleburne—Imhoff, settling, degasification, sludge circulation with automatic vacuum pump, sprinkling filter.

Houston—First large activated sludge plant in the world, new sludge filtering equipment recently completed.

San Marcos—One of the first and smallest activated sludge plants in the world.

San Antonio—Large-scale broad irrigation with raw sewage, new activated sludge units under construction.

The Sewage Research Station at Texas A. & M. College, College Station, Texas, under the direction of Professor F. E. Giesecke, jointly with the Sanitary Engineering Division of the State Department of Health, has extended Dr. Imhoff all facilities in arranging for other conferences and inspections of other plants.

California Sewage Works Association Spring Conference, March 20–21, 1929 Fresno, California

The California Sewage Works Association held its first Spring Conference March 20–21, 1929, at the City Hall, Fresno, California. An attendance of 123 was recorded.

The meeting was called to order at 10:00 a.m. March 20 in the auditorium of the San Joaquin Light and Power Company. An address of welcome was tendered by Mayor A. E. Sunderland of Fresno and the response for the association was delivered by the President, Prof. Leon B. Reynolds.

Two technical papers were presented at this meeting; (1) "Pumping Sewage," by Herbert Paterson, Asst. City Engineer of Long Beach, with discussion led by Thos. Warburton, councilman, City of Madera, and (2) "Imhoff Tank Operation," by L. H. Gadsby, City Engineer, Visalia, with discussion led by W. B. McWharter, Superintendent of Sewers, Exeter.

In the afternoon Mr. C. C. Kennedy, Consulting Engineer, Oakland, discussed the new sewage plant at Lemoore, which was visited the following (Thursday) morning. A round-table discussion on "Experiences with Flat Sewer Grades" was led by Andrew Jensen, Fresno; F. J. Rossi, Modesto; R. M. Berryhill, Tulare; and others.

The Fresno sewer farm was visited at 4:00 p.m., following a description of the plant by Commissioner Andrew Jensen.

The first evening was enjoyably spent at a joint dinner with the San Joaquin Valley Section of the League of California Municipalities. An

illustrated lecture by Prof. Charles Gilman Hyde, University of California, Berkeley, on "Recent Sewage Disposal Practice in Europe" was greatly appreciated.

The second day, March 21, was spent in visits to four sewage treatment works in the vicinity of Fresno.

The Lemoore plant was visited at 9:00 a.m. It consists of Simplex aerators, Dorr clarifier, trickling filters and sludge beds.

The Tulare plant was reached at 11:00 a.m. The features of particular interest were the Link Belt clarifiers, separate sludge digestion, activated sludge plant (not in use) and an excellent sewer farm.

After luncheon the Visalia plant was visited. These works include four large Imhoff tanks and a sewer farm.

The final plant visited was at Rudley, where inspection was made of Imhoff tanks, trickling filters with secondary sedimentation and natural sand beds for intermittent filtration.

The party disbanded at 4:30 p.m. at Rudley.

The program for this conference was prepared by the Program Committee, B. J. Pardee, City Manager, Visalia, Chairman. Andrew Jensen, Commissioner of Public Works, City of Fresno, was in charge of local arrangements.

The officers of the California Association are as follows:

President: Leon B. Reynolds, Stanford University, Palo Alto.
First Vice-President: F. A. Batty, 942 Bronson Ave., Los Angeles.
Second Vice-President: B. J. Pardee, City Hall, Visalia.
Secretary-Treasurer: E. A. Reinke, University of California, Berkeley.
Directors:
F. M. Lockwood, City Hall, San Diego, one-year term.
A. W. Wyman, Supt. Sewage Works, Pasadena, two-year term.
Philip Schuyler, 114 Sansone St., San Francisco, three-year term.
A. K. Warren, 202 Law Bldg., Los Angeles, four-year term.
C. G. Gillespie, Univ. of California, Berkeley, five-year term.

New Jersey Sewage Conference Group
Trenton, March 22, 1929

Notice was given in the January, 1929, issue of THIS JOURNAL (p. 119) concerning the preliminary meeting of the New Jersey Sewage Conference Group.

The first annual meeting of this group was held March 22, 1929, at Trenton, in conjunction with the New Jersey Sewage Works Association.

Officers elected were: Willem Rudolfs, Chairman; John R. Downes, Vice-Chairman; Richard C. Smith, Secretary. Dr. Rudolfs and Mr.

Smith were appointed representatives of the group on the Board of Control of the Federation of Sewage Works Associations.

The membership of this conference group at the time of the meeting was 45, most of whom were present. The list of members is increasing rapidly; the group included only twenty when organized in January. Members of the New Jersey Sewage Works Association or others in New Jersey interested in the aims of this conference group may obtain further information by communicating with the chairman, Dr. Rudolfs. He will explain the benefits to be derived by membership.

Central States Sewage Works Association Notice of Second Annual Meeting

The Second Annual Meeting of the Central States Sewage Works Association will be held in Indianapolis, Indiana, in June, 1929, probably just preceding the meeting of the American Water Works Association in Toronto, June 24 to 28, 1929.

Lewis S. Finch, State Sanitary Engineer of Indiana, is Chairman of the Committee on Arrangements. Paul Hansen, 6 North Michigan Avenue, Chicago, is Chairman of the Program Committee. The program will probably contain papers dealing with various phases of operation of the activated sludge plants at Milwaukee, Chicago and Indianapolis, and additional papers on features of operation of the smaller treatment works in Illinois, Indiana and Wisconsin.

Robert Cramer, Chief Engineer of the Milwaukee Sewerage Commission, is President of the Association. Gus Radebaugh, Urbana, Illinois, is Secretary and L. F. Warrick, Madison, Wisconsin, is Treasurer.

Definite announcement of the exact date of the meeting will be sent to the members as soon as it has been determined.

Reviews and Abstracts

Sludge Circulation—A Recent Development in Sludge Digestion in Germany

ABSTRACTED BY G. P. EDWARDS

In 1927, Dr. Max Prüss[1] of the Emschergenossenschaft, Germany, reported the development of a mechanical aid for hastening sludge digestion. He proposed vertical circulation of the contents of a digestion tank. The circulating apparatus consists of a rotating screw driven by a vertical shaft directly connected to an electric motor situated above the center of the cover of the sludge tank. The screw revolves in an open uptake pipe about one meter below the surface of the sludge. The pipe extends from the bottom of the hopper to the surface of the sludge liquor.

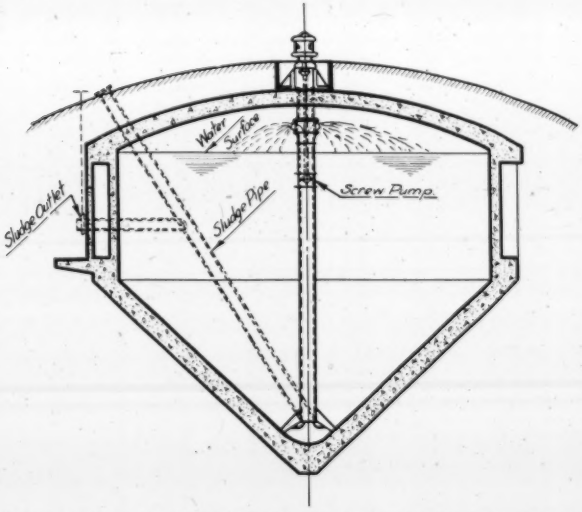
The screw pump is operated for about two hours daily, sufficient to rotate the entire contents of the tank. Prüss reports that fresh solids thus circulated can be digested in about one-half the time ordinarily required. Figure 1 shows a plan of such a separate sludge digestion tank at the Essen-Nord works.

Theory.—Circulation is assumed to provide favorable environment for the bacteria responsible for digestion by bringing fresh organic material to the active bacteria and by removing the gaseous products of bacterial action. This is considered to be beneficial, since decomposition is probably accomplished in two steps; in the first stage, solid organic substances are liquefied by enzymes; in the second stage, the materials so liquefied enter the bacteria. There they are further decomposed by cell protoplasm so that the cleavage products of the bacteria can be used for the building of their own bodies or to furnish life energy. This energy is furnished in general through slow burning of carbon to carbon dioxide. The carbon dioxide goes into solution in the surrounding water. The solubility of carbon dioxide increases with increasing depth of the sludge tank. At the bottom of a 30-foot tank, it is about twice as soluble as at the surface. When the concentration of carbon dioxide in the water surrounding the bacterial cells becomes great enough, activity may be retarded.

The other main decomposition product of sludge digestion is methane, which is only sparingly soluble in water. Normally the liberated gas remains close to the bacteria. The very small sludge particles cling together and finally accumulate a gas covering which completely separates the bacteria from the sludge water. Then the absorption of food stops, and with

it, the decomposition of sludge by these bacteria. When the screw pump is started, the sludge is forced from the bottom of the tank through the sludge pipe to the surface, so that the small gas bubbles expand to twice their volume and, assisted by the rotating paddles, free themselves from the bacteria. At the surface, half the soluble carbon dioxide is lost and a further decrease in concentration occurs on mixing with the surface water.

The solid sludge particles forced to the surface sink through the sludge liquor to the upper sludge surface. As the sludge particles fall through the



Separate Sludge Digestion Tank with Screw Pump for Circulation of Sludge.

sludge liquor the soluble end-products, assumed to be toxic, are distributed throughout the liquid.

Applications of Sludge Circulation.—The stirring apparatus was originally designed for a separate sludge tank. However, since the motion of the sludge in the digestion tank takes place only vertically, this rotation can also be used in two-story tanks with slots opening into the settling chamber, without disturbing the settling action. An Imhoff tank at the Essen-Nord works has been used in this way for some time. It is claimed by Prüss that the rotation of the sludge nearly doubles the efficiency of the digestion tank.

Sludge rotation is also claimed to solve the scum problem. By reversing the pumping apparatus the scum is drawn from the surface, broken up by the rotating paddles and drawn under the settled sludge. Most of the scum remains in the settled sludge and is digested there. The floating scum is thoroughly inoculated with methane-producing bacteria so that digestion proceeds without odor.

Cost of Sludge Rotation.—The cost of sludge rotation is relatively low in installation as well as operation. In a sludge tank with a capacity of about 16,000 cu. ft., an electric motor of 3.6 kw. rating has been installed. This motor is used only two hours per day. The cost of electric current amounts to only a fraction of the value of the gas liberated.

Operating Data.—In July, 1928, Prüss[2] reported some results from the Frohnhausen plant, where an investigation was made with settled solids in a circular tank having a capacity of 17,650 cu. ft. The sludge, heated to 77° F., was digested to a moisture content of 80 per cent, first without and then with sludge rotation, and finally to complete digestion with rotation. The sludge was circulated twice daily by means of a screw pump having a capacity of 150 gallons per minute.

The solids added to the tank amounted to 0.11 pound per capita per day, of which 70 per cent was volatile matter. Based on a reported weight of gas of 0.063 pound per cubic foot and 67 per cent digestion of volatile matter, 87 per cent of the volatile matter by weight was gasified. The comparative results for gas yield are shown in Table 1.

TABLE 1

GAS PRODUCED AT FROHNHAUSEN

Condition	Cu. Ft. Gas per Capita per Day	Cu. Ft. Gas per Lb. Volatile Matter	Time of Digestion—Months
Without rotation to 80% moisture	0.35	4.55	2.0
With rotation to 80% moisture	0.41	5.32	1.33
Without rotation to complete digestion	0.70	9.10	2.67

Results at Essen-Rellinghausen.—In September, 1928, Fries, of the Ruhrverband, while discussing the effect of artificial heating and circulation of sludge, reported some results from the Essen-Rellinghausen plant on two Imhoff tanks fitted with sludge circulation apparatus. The Imhoff tanks at the Essen-Rellinghausen plant are heavily overloaded and an attempt was made to increase the efficiency of two tanks by rotating their contents. The test was carried on from April 13 to May 10, 1928, thus lasting about a month. The sludge was pumped from the bottom to the top of the sludge compartment by means of a diaphragm pump.

The quantity of gas obtained from the tanks with rotation was slightly larger than from the tanks without rotation, as shown in Table 2. In general the results of Prüss were not confirmed. In the first place, after rotation, the water content which had previously varied from 82 to 90 per

cent was completely equalized so that it was uniformly 95 per cent. In a quiescent tank there is a lower moisture content and a higher percentage of mineral matter in the sludge in the deeper layers. According to this investigation, rotation of the digestion room contents not only had no practical advantage but it even yielded a poorer sludge.

Fries reported that the analyses of the gases from the digestion tank with rotation showed further that the carbon dioxide content was considerably higher than in the tank without artificial mixing. On the average, the CO_2 content was 25 per cent higher with a maximum of 36 per cent. The increased amount of CO_2 decreased the value of the gas.

Prüss' Reply to Fries.—Prüss[4] doubts the accuracy of Fries' data. The experiments at Essen-Rellinghausen were carried out for only four weeks. This period is too short to obtain conclusive results, since, for unknown reasons, there are many fluctuations in the amounts of gas obtained even under normal operation.

According to Fries' description of the experiment, the sludge was circulated with a diaphragm pump. Prüss does not know of a gas-tight diaphragm pump and concludes that a large part of the gas was lost during circulation. The rate and frequency of pumping was not mentioned.

TABLE 2

RESULTS OF SLUDGE ROTATION EXPERIMENTS AT ESSEN-RELLINGHAUSEN

Values Obtained from Curves. Gas in Cubic Meters

Days	Sludge Rotated from 26 to 53 Days	Sludge Rotated from 28 to 55 Days	Sludge Not Rotated
10	200	200	200
20	400	400	400
30	700	650	650
40	1000	900	950
50	1350	1250	1250
63	1800	1650	1600

Prüss intimates that possibly the moisture of the sludge from the quiescent Imhoff tanks was higher than that from the tank in which the sludge was circulated.

Prüss[5] had previously covered Fries' objections to the increased amount of CO_2 by the argument that dilution of the methane with CO_2 brought the heating value down to that of illuminating gas, thus making it possible to use it in gas burners without further adjustment of the air supply.

In his most recent publication, Fries[6] claims that his results are correct as they were taken from actual operating data of the Ruhrverband. He states that Prüss' claims are too theoretical, not being based on practical experience.

Discussion (Abstractor).—Fries' experiments at Essen-Rellinghausen with sludge rotation were carried on for only four weeks. This is too short

a time to give conclusive results as to the possibilities of the process. From the low yield of gas obtained it is possible that some gas was lost during circulation or from leaky covers. In addition to this, the experiments were made in Imhoff tanks, which are probably not as well adapted to sludge rotation as separate digestion tanks.

On the other hand, Fries' objections to the use of sludge rotation on the basis of increased moisture in the sludge and increased amount of CO_2 in the gas are well taken.

More data from plant installations are necessary to decide the merits of Prüss' ideas.

[NOTE: Prüss' theories and data regarding the effect of heat insulation on sludge digestion will be covered in future abstracts.]

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Report of Deputation to Germany (July, 1928) Re: Sewage Treatment, with Special Reference to Sludge Disposal*

BY J. E. HUTCHINSON, H. F. ROBINSON AND E. ARDERN, RIVERS DEPARTMENT, MANCHESTER, ENGLAND

A short account of the work of the Emschergenossenschaft and the Ruhrverband and information regarding the various disposal works visited is given in the following abstract.

The Emschergenossenschaft.—The drainage area of the Emscher lies in the heart of the Rhenish-Westphalian industrial district, surrounded by the watershed of the Lippe and the Ruhr. The valley is 43 miles long by 12 miles wide and covers a total area of 300 square miles.

In July, 1904, the Emschergenossenschaft was formed for the regulation of the river and for sewage purification in the Emscher district.

The general policy has been to reconstruct the course of the Emscher River and its tributaries, to secure a self-cleansing velocity and at the same time to ensure the proper drainage of the low-lying land in the area. Pro-

* Abstracted by C. T. Wright.

visions have been made for future deepening to allow for the sinking of land due to mining operations.

To avoid flooding during high water in the Rhine, the flow of the Emscher has been diverted at Oberhausen through a specially constructed water-course (New Emscher) to the Rhine. The original (reconstructed) water-course (Old Emscher) from this point has been retained to drain the district through which it passes.

It has been considered economically unsound to entertain complete purification (oxidation) of the domestic sewage and industrial waste in such a densely populated industrial area, as the dilution of the Rhine is available for final purification. The policy has therefore been adopted of limiting the treatment of sewage to the removal of settleable solids which would interfere with the free flow of the stream.

The Board controls 26 sewage treatment plants and three stream purification plants, and other works are projected for treating the whole Emscher flow with the object of reducing the suspended matter content, which consists mostly of coal dust from coal-washing plants. The total expenditure already incurred amounts to $19,000,000, approximately.

The Ruhrverband.—The basin of the Ruhr covers an area of 1730 square miles with a total population of 1,250,000.

In the Ruhr valley are situated 90 water works, supplying a total volume of 250 m. g. daily. In general, the water is taken from wells and infiltration galleries about 150 feet from the river; hence purity of the river is essential.

The Ruhr Purification Bill, which was passed in June, 1913, controls the policy to be followed in the purification of sewage to obviate pollution of the Ruhr.

The Ruhrverband has divided the whole area into three zones, "A," "B" and "C." Zone "A" includes the large towns, Mulheim, Duisberg and Oberhausen. It has been deemed advisable and economical to build an intercepting sewer conveying the sewage of this area from the Ruhr to the Rhine, where it receives treatment in Emscher tanks prior to being discharged into the river. Zone "B" is the proper water works line which extends from Mulheim upwards to Hengstey where the River Lenne joins the Ruhr, and in this district complete sewage purification plants yielding a high quality effluent are required. Zone "C" is mainly sparsely populated woodland and the degree of sewage treatment is governed by local conditions.

The Emschergenossenschaft and the Ruhrverband have carefully studied the problem of sludge disposal by secondary digestion with recovery of the resultant gases, and as a result this means of sludge disposal is being generally adopted throughout both watersheds.

Sewage Works.—During the investigation, 15 representative towns and cities were visited, six coming under the supervision of the Emscher

Board, three under the Ruhr Board and six outside of the two districts. A short account of the sewage disposal problem appears for each place, including data pertaining to the present methods of sewage disposal and plans for future developments, with special reference to the particular type of treatment, quantity of gas collection and its utilization, separate sludge digestion and sludge disposal.

Sewage treatment with Emscher tanks, incorporating some modifications, is practiced in eleven of the cities. At three of the cities Emscher tanks are used in combination with the activated sludge process; at four, Emscher tanks in combination with separate sludge digestion, and at one, Emscher tanks with submerged contact aerators. Screening plants are used at Dresden and Cologne, the River Elbe being used for dilution by the former city and the Rhine by the latter.

The greater part of Berlin's sewage is disposed of on sewage farm lands, 18 m. g. daily being treated in Emscher tanks at Wassmannsdorf. Future developments include activated sludge plants at Wassmannsdorf and Stahnsdorf to deal with 22,000,000 gallons of sewage per day.

The report points out that secondary digestion, with recovery and utilization of the gaseous products of fermentation, is being adopted in Germany as the best and most economical means of sludge disposal.

The importance of temperature in accelerating the digestion process is considered essential to the economical application of the process. It is claimed that with the maintenance of a temperature approaching 25° C. and the regular and thorough incorporation of the additional fresh sludge with ripe sludge, the cubic capacity of the digestion tanks need not exceed one cubic foot per capita, and the gas production will amount to from 0.5 to 0.7 cubic foot per capita daily.

Although subject to some variation in its composition, the gas evolved consists, in general, of methane (CH_4) (70 to 75 per cent), and carbon dioxide (CO_2) (25 to 30 per cent), with trifling amounts of nitrogen and hydrogen.

The thermal value of the gas (650 B. t. u.) is considerably higher than that of ordinary town gas (450 B. t. u.). The price obtained for the gas from the sewage works in Germany varies from 24¢ per 1000 cubic feet in the Essen and Ruhr districts to 48¢ per 1000 cubic feet in the Stuttgart district.

In no instance was any aerial nuisance observed, which might be attributable to the digested sludge discharged from the digestion tanks.

Sewage Sludge*

By J. H. Garner

Surveyor, Vol. **74**, No. 23, 1928, pp. 465-9

The problem of sludge disposal is of paramount importance in the treatment of sewage. The method of disposal depends primarily upon local conditions and possibilities. The amount and character of the sludge to be handled, site restrictions, economy of operations and other factors must be considered in sludge as well as in sewage disposal, and the methods of disposal devised or evolved must fit the particular local conditions. These methods fall into two groups, namely: (1) disposal without dewatering; and (2) disposal with dewatering.

Disposal of wet sludge requires large areas of land in proportion to the amount of sludge to be handled, unless the wet sludge can be dumped into the sea or other large body of water.

Trenching or ploughing is a cheap and satisfactory method when carried out according to a carefully devised plan. Badly devised or careless procedure always causes nuisance and renders the land unworkable. Much of the unfavorable comment on this method has been caused from careless or thoughtless management.

The land areas required for the disposal of wet sludge, from figures based upon statistics from several sewage works, are: for weak domestic sewage sludge, 1.25 sq. yds. /capita; for medium domestic sewage sludge, 1.5 sq. yds./capita; for strong domestic sludge with some trade wastes, 1.75 sq. yds./capita.

This type of disposal has been used successfully at a large number of small and several large works. The greatest difficulty lies in the delays and troubles caused by unfavorable weather.

Where conditions make the direct disposal of wet sludge impossible, dewatering must be adopted in order to reduce the bulk and render the sludge transportable. The disposal of the dewatered sludge is a local matter, but the dewatering process involves many scientific and practical matters and offers a large field of invention.

The most common method of dewatering is by filtration through sand. Sludge beds of various types, kinds and degrees of efficiency have been used, and with careful attention to construction and management, such filters are adaptable to most plants. Capacity of sludge beds from statistics of 66 Yorkshire plants show averages of 12.5 persons/sq. yd. of filter for ordinary domestic sewage; 9 persons /sq. yd. for strong domestic sewage; and 4.5 persons/sq. yd. for trade wastes. The filter area should be divided into sufficiently small units to allow for easy manipulation, and should be covered for protection from bad weather.

* Abstracted by C. T. Carnahan.

Dewatering by means of filter presses is a dirty and costly method, which can be economically used only where a market exists for the sludge cake produced. With proper buildings, machinery and market for the cake, the dirt may be eliminated and the cost reduced so that the method is attractive, but the present tendency is away from filter presses unless they are absolutely required by local conditions.

Reduction of moisture content may also be accomplished by separate sludge digestion. This method has come into favor lately, and is still being investigated. At the sewage works at Bath, separate digestion has reduced the bulk to about 46 per cent of that of the undigested sludge and the air-dried product is granular and friable.

Some of the problems of separate digestion are—capacity of tanks required, temperature of digestion, alkalinity, proportion of ripe sludge to fresh sludge entering the tank, and collection and utilization of the gases produced. In the United States and Germany attempts are being made to correlate the size of tanks with the population served, but such correlation is difficult without strict regulation and control of the digestive process. The gases produced may be utilized to heat the tanks and so speed up digestion.

Separate digestion has advantage in that there is little or no odor, there is a saving of labor in handling sludge, which dries and filters easily, gases produced may be used, and the dried product may be sold as fertilizer. The greatest difficulty in preparing sludge for fertilizer lies in the drying of the sludge to less than 15 per cent moisture. A recent development is a dryer similar to those used in the beet sugar industry, which dries the sludge at rather low working temperatures, allowing the wet material to dry slowly and uniformly without charring.

As to the production of fertilizer from sludge, it must be borne in mind that the greatest production of sludge occurs in the densely populated, non-agricultural areas, and that in many cases the sludge is returned to the ground locally without special treatment. In many cases the amount of sludge produced is too small to warrant extensive drying. The main problem is the removal, economically, of the sludge from the cities to the agricultural areas where there may be a demand for it. The problem of sludge disposal is therefore still more of a local than a national problem.

Report of the Water Pollution Research Board for the Year Ending June 30, 1928

ABSTRACTED BY H. R. CROHURST

The Water Pollution Research Board, of which the first report has become available, was appointed in June, 1927, as a part of a comprehensive

plan of the British government for dealing with the pollution of rivers and streams.

The duties of the Board are threefold: to collect and collate all pertinent scientific and technical information, in order that it may be readily available for practical application by those concerned with water supply and the disposal of polluting liquids; to encourage and coördinate relevant scientific research in the country; and to undertake such investigations as are necessary in the public interest and not otherwise provided for.

Monthly summaries of current literature have been compiled and issued during the first year under the headings of water supplies sewage, trade waste waters, river pollution and miscellaneous. Plans have been made for a general biological and chemical survey of the River Tees, a typically polluted English river, which, starting from its source as a pure stream, receives a variety of domestic and industrial effluents and ends in a tidal estuary; for a study of the zeolite process of water softening and a study of the biological factors involved in the activated sludge process of sewage treatment.

Preliminary laboratory experiments on the purification of beet sugar factory effluents having indicated that biological filtration appeared promising, experiments on a semi-commercial scale were undertaken with the coöperation of the industry at representative plants. Removal of the grosser suspended matter from the combined wastes by screening and settling in ponds, before discharge to the watercourse has been the common English practice in disposing of this type of waste, a procedure not altogether satisfactory. Less efficient treatment of the waste water is required for its reuse than for discharge into streams and the tendency of the industry is toward the reuse of such water, where possible, with subsequent diminution in the volume of wastes. Treatment for reuse offers numerous problems but there is no reason to believe they cannot be solved, in a large number of cases, and that the experiments on biological filtration or some other method of treatment will lead to a suitable method of purification of such waste waters as must of necessity be withdrawn from the processes of manufacture.

A detailed description of the experimental plants and the results obtained during the limited investigation before the beet sugar manufacturing season of 1927 closed is presented in the first annual report of the Director of Research, Dr. H. T. Calvert, which accompanies the report of the Board.

The Advantages of Different Types of Sewage Tanks*

By WM. CLIFFORD

Surveyor, Vol. 73, No. 1899, 1928, pp. 645–7

Many attempts have been made to connect the amount of suspended matter deposited in a sewage tank with the rate of flow through the tank. The measurement of the mean velocity of flow in model tanks, using the salt-curve method, is possible when the water is turbulent, but unreliable when conditions favor sedimentation. Baffles have proved ineffective in controlling movement of water in the case of slow motion. Observations in model tanks have shown: (*a*) the form and position of the inlet have marked effect in determining the movement of the liquid; (*b*) turbulence increases with kinetic energy, where provision is not made for absorbing such energy of the inflowing liquid; (*c*) baffle walls and deep scum boards produce "dead" water and limit the working capacity of the tank; (*d*) a bell-shaped orifice to the inlet pipe has no effect on the direction of flow of the incoming liquid.

The capacity of detritus or grit tanks need not exceed $^1/_{120}$ of the daily flow, but additional tanks with capacity of $^1/_{360}$ of dry-weather flow should be provided for automatic service at three times dry-weather flow.

Almost any shape of tank will serve for continuous-flow sedimentation. The hopper tank is useful for humus or light sludge. Deep scum boards maintain "dead" water near the surface; shallow floating baffles are more effective. Unguarded submerged inlets and outlets promote short circuiting. With properly guarded inlets there is no necessity for long tanks. The advantages of shallow as compared with deep tanks are: (*a*) lower cost, (*b*) possibility of larger units, (*c*) small loss of level for cleaning, and (*d*) production of denser sludge. Temperature and density usually are not controllable.

For effective action of septic tanks, the fresh liquid should be mixed with the older liquid, followed by sedimentation in a separate tank.

Storm water tanks must be emptied frequently. This limits construction to the shallow rectangular type. These tanks should be designed to facilitate removal of sludge.

* Abstracted by H. W. Streeter; courtesy U. S. P. H. S. Engineering Abstracts.

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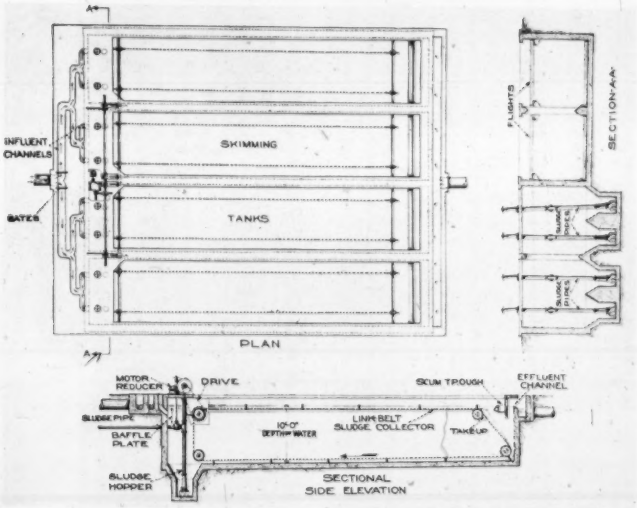

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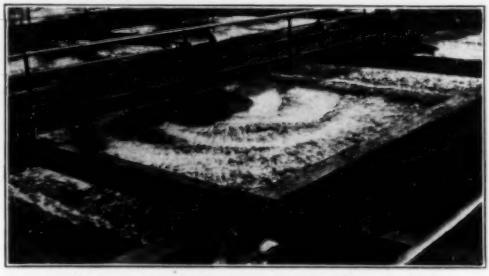

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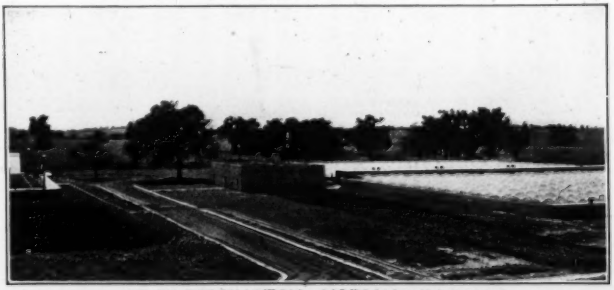

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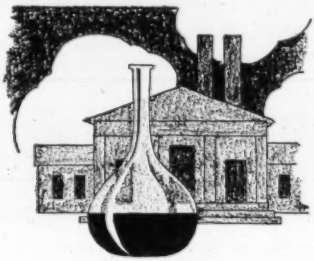

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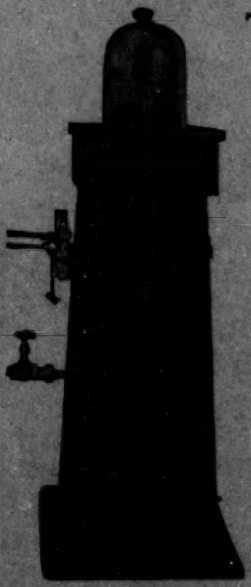

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